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Gulf Regional Sediment Management Master Plan: Case Study Compilation

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ABSTRACT

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Eleven habitat restoration case studies were summarized for a variety of habitat types, restoration goals, and project sizes. Each project had unique characteristics that required its own specific approach to habitat restoration/creation, habitat conservation, and beneficial use of sediment required for restoration. However, in every case, the underlying theme associated with restoration or conservation was effective use of sediment. For example, upland disposal of dredged material for bird habitat to avoid adverse impacts of increased turbidity on seagrass beds worked well for Laguna Madre, but Louisiana used similar material for containment dikes and marsh restoration. In both cases sediment was used for habitat restoration rather than disposed of outside the active sediment system. Project success for all case studies depended upon clear and consistent communication among stakeholders. Addressing concerns associated with proposed restoration early in the process builds confidence among stakeholders and a level of trust that often carries through the project approval process.

ADDITIONAL INDEX WORDS: *Habitat restoration, beneficial use of dredged material, Texas, Louisiana, Mississippi, Alabama, Florida, northern Gulf of Mexico.*

INTRODUCTION

The Habitat Restoration and Conservation Team (HCRT) under the Gulf of Mexico Alliance (GOMA) recognizes the importance of sound management principles for the use of riverine and coastal sediment resources toward maintaining the health and vitality of the Gulf of Mexico ecosystem. As such, the Gulf Regional Sediment Management Master Plan (GRSMMP) was established to facilitate and assess the implementation of sediment management for more effective use of dredged material and other sediment resources for habitat creation and restoration. The intent of the plan is to provide guidance to Gulf States for effective management of sediment resources, recognizing they are a part of a regional system involving natural processes and dredging activities. Issues surrounding sediment management, including natural movement and dredged sediments, have significant impact on the ability to restore and sustain coastal habitats. Effective sediment management must occur on a regional scale unencumbered by agency, State, or national boundaries.

In an effort to develop a sediment management plan that illustrates an understanding of sediment dynamics (inputs, outputs, and movement) relative to available sediment resources to accomplish environmental restoration and conservation, while reducing coastal erosion, storm damages, and associated costs of sediment management, this chapter of the GRSMMP aims to document existing and completed beneficial-use projects to yield lessons learned toward developing improved regional sediment management (RSM) plans. Eleven RSM studies of dredging and other similar projects are summarized using the following general outline. Case study locations are situated throughout the northern Gulf of Mexico (Figure 1) and reflect various project scales from Florida to Texas that illustrate impediments and successes that were realized when implementing a RSM approach. The following outline format was followed for each case study.

Case Studies Evaluation Outline

I. *Project Site Location*

(1) Physical Setting
(2) Geomorphic Region (barrier island, mainland, bay, deltaic, chenier plain)
(3) Coastal Processes (waves, currents, tides)

II. *Project Description*

(1) Overview (project authority, funding, motivation)
(2) Policy and Management Issues
(3) Current/Recent Funding
(4) Identified Problems and Management Issues
(5) Monitoring

III. *Project Outcomes*

(1) Ecological and Physical (Direct Benefits/Impacts)

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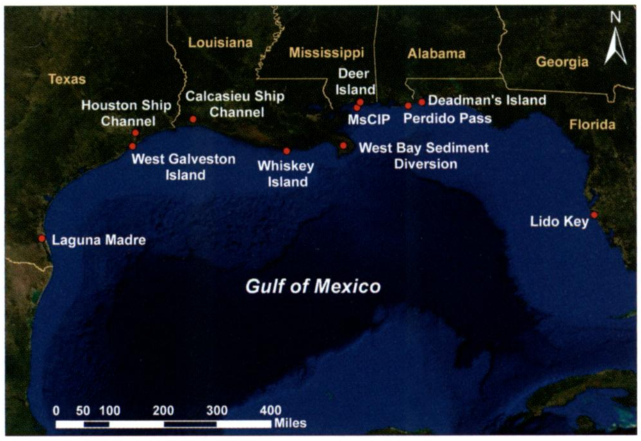

Figure 1. Locations for 11 regional sediment management case studies.

(2) Economics/Project Efficiencies (Secondary Benefits/ Impacts)
(3) Missed Opportunities

IV. *Regional Sediment Management Principles Applied*
V. *Lessons Learned and Recommendations*

Seven RSM operating principles, developed by the U.S. Army Corps of Engineers (USACE), Mobile District, provide a basis by which case studies are evaluated. Depending on scale, not all operating principles apply to each case study. However, most do apply and provide a systematic means of evaluating project effectiveness relative to RSM. The process requires an objective evaluation of project goals and accomplishments relative to sediment resources and sediment management practices. The underlying question is whether project implementation considers the most basic principles of sediment management when dredging, habitat restoration, and/or habitat creation are the primary actions. Each case study was evaluated relative to the following RSM principles.

(1) Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area. Evaluate the use of all sediment resources for implementing sound RSM practices.
(2) Seek opportunities to implement RSM practices and procedures to improve sediment management. Strive to achieve balanced, sustainable solutions to sediment-related issues.
(3) Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures. Partner with stakeholders to balance objectives and leverage resources.
(4) Make local project decisions in the context of the sediment system and consider the regional implications beyond the local site, beyond project-intended effects, and over longer time scales (decades or more). Evaluate the impacts of individual projects on adjacent projects and the regional system.
(5) Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions. Apply RSM principles to the entire watershed and include watershed impacts in the evaluation of coastal projects.
(6) Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale. Seek opportunities to improve project efficiencies and minimize negative impacts.
(7) Apply technical knowledge and tools and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.

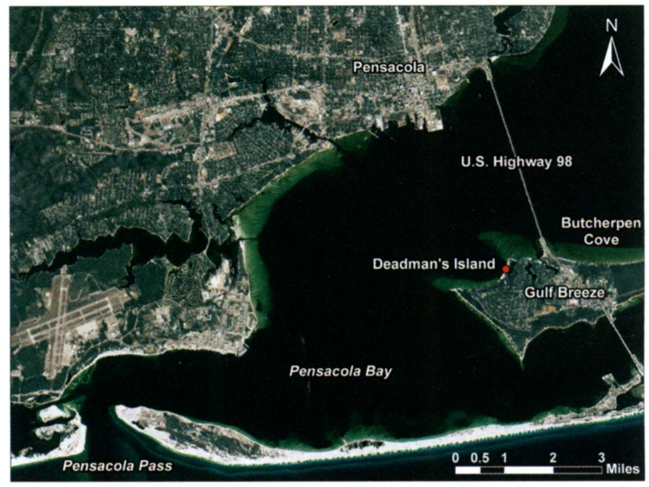

Figure 2. Location diagram for Deadman's Island.

Figure 1 illustrates case study locations and project names for the northern Gulf of Mexico. Projects exist at all scales and under various Federal, State, and local authorities. However, all projects are focused on coastal restoration within the framework of RSM principles.

CASE STUDIES

The section that follows includes a project summary for each of the case study locations illustrated in Figure 1. These studies reflect a variety of project scales and restoration/ habitat project goals. However, the common theme was recognizing sediment as a resource and designing ways to ensure sediment was used effectively for habitat restoration/ creation and/or conservation.

Deadman's Island Aquatic Ecosystem Restoration

Project Site Location

Deadman's Island is located in the City of Gulf Breeze, Florida, on the NW end of the Fairpoint Peninsula in Pensacola Bay (Figure 2). The project area encompasses approximately 134,000 square ft off the N and NW ends of Deadman's Island and slopes from approximately +2 ft mean sea level at the shoreline to about −3 to −4 ft offshore (Rees *et al.*, 2003).

Fairpoint Peninsula is a barrier island of Pleistocene age composed predominantly of quartz sand. The bluffs on its

Figure 3. Sand shoal and sand waves north of Deadman's Island and Highpoint Bluff illustrating sand transport by waves and currents.

western and northern perimeters are composed of unconsolidated medium-grained sand, with only minor amounts of finer-grained material (Morgan, 1993). In response to sea-level rise and storm activity, sediment has been eroded from these bluffs and transported to the west by longshore currents during frontal storms (Houser, 2007). A broad sand shoal and sand waves north of Deadman's Island are evidence of the constant movement of sand being eroded and transported by waves and currents (Figure 3; Morgan, 1993). Winds are typically from the N-NW in fall and winter and from the S-SE in spring and summer (Rees *et al.*, 2003).

Analysis of historical shoreline position since 1940 indicates the northern and western shorelines of Deadman's Island have receded, while the SW shoreline experienced little change (Figure 4). Erosion along the north shore is the result of a localized imbalance in sand transport where sand being transported out of the system by waves and currents is derived from either cliff erosion, longshore drift, or cross-shore transport (Houser, 2007). Between 1968 and 1978, the Highpoint Bluff shoreline east of the project site was stabilized by seawalls and bulkheads, limiting longshore sediment supply to Deadman's Island from these bluffs and increasing shoreline recession and beach erosion (Morgan, 1993). Another factor contributing to increased erosion rates may have been the construction of "Three-Mile Bridge" (U.S. Highway 98), which may have restricted sediment transport from Butcherpen Cove, located east of the bridge (Figure 3). Shoreline recession on the northern spit of Deadman's Island may also be a result of sediment washover during large storms with north winds (Houser, 2007). The sand spit provides protection for salt marshes located between Deadman's Island and the mainland (Reed, 2008). The Florida Department of Environmental Protection has designated this area of Deadman's Island as a critical shoreline erosion site (Rees *et al.*, 2003).

Project Description

In 2003 the USACE, Mobile District, prepared an Environmental Assessment for an Aquatic Ecosystem Restoration project on Deadman's Island. The purpose of the project was to protect the degrading salt marsh on the north shore from erosion due to wave energy while increasing the productivity of the Gulf Breeze aquatic area. The project site had turned biologically unproductive due to a lack of vegetation that offers protection preferred by most marine organisms. Authority came from Section 206 of the Water Resources Development Act of 1996, which provides for USACE

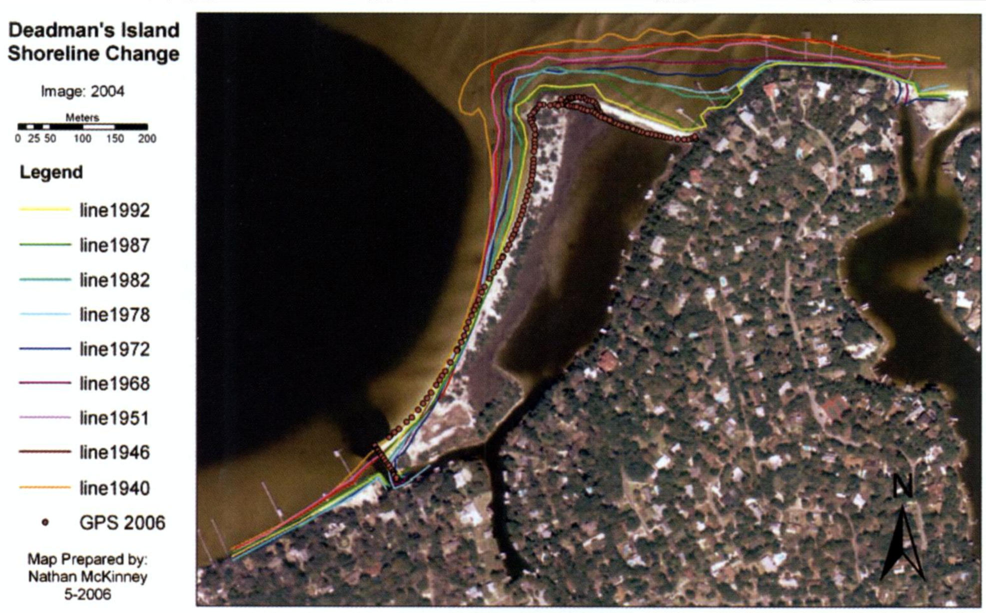

Figure 4. Historical shorelines at Deadman's Island for the time period 1940–2006 (from Houser, 2007).

restoration of degraded aquatic ecosystems. The Federal sponsor for the Deadman's Island project was the USACE, Mobile District; the non-Federal sponsor, the City of Gulf Breeze, Florida, agreed to pay 35% of the total project costs as well as maintain and operate the project upon completion. The proposed Deadman's Island project consisted of placing 295 artificial reef structures 200 to 400 ft offshore along approximately 1240 linear ft of shoreline. The reef structures would dissipate high wave energy, thereby protecting shallow water and beach habitat, as well as the many cultural resource artifacts identified in the project area. Restoration would also involve approximately 45,300 square ft of planted emergent salt marsh stabilized with filter fabric for shoreline protection and an additional 2025 square ft of planted coastal dune vegetation for dune stabilization and habitat diversity (Rees *et al.*, 2003).

The proposed project, designed by the Mobile District, was in the permitting process until 2005, when the permit was withdrawn due to depleted funding. In 2007 the City of Gulf Breeze reopened the project and became the sole applicant. Grant funding was initially provided by the Florida Office of Coastal and Aquatic Managed Areas (CAMA) in support of the island becoming an aquatic preserve after restoration. The newly proposed project was focused on improving the aquatic environment of Deadman's Island, preventing further erosion of the island, and preventing exposure of historical cultural resources located in the project area. Changes to the project plan included using a ReefBLK, an innovative oyster reef structure specifically designed for breakwaters and advanced ecosystem habitat in estuarine areas instead of an artificial reef structure, and beneficially using sediment from nearby dredged material disposal sites for fill between the breakwater and the island (Reed, 2007).

An investigation was conducted by the Florida Department of Environmental Protection's Florida Geological Survey (Phelps, Ladle, and Sparr, 2008) to better understand the surface geology of Deadman's Island, to understand the nature and distribution of seafloor sediment adjacent to Deadman's Island, and to determine if sediment from dredged material disposal areas, one located on the south end of Deadman's Island at the entrance to Gilmore Bayou and the other to the NE of Deadman's Island at the entrance to Woodland Bayou, sufficiently matched sediment in the project area for restoration purposes. It was concluded that sand in both proposed borrow sites had acceptable grain size characteristics, although sand in the site NE of the island was slightly finer grained and sand in the site on the south end of the island was slightly coarser grained (Phelps, Ladle, and Sparr, 2008). Future plans include beneficially using sediment from nearby dredged material disposal sites as fill for newly created marsh and cover for the unearthed historical cultural resources in the project area (Figure 3; Reed, 2007). As of 2011, the dredge and fill permit submitted by the City of Gulf Breeze in July 2008 remains under review by the Florida Department of Environmental Protection.

In 2010, during Phase 1 of the Deadman's Island project, 810 ft of ReefBLK breakwater structures were placed approximately 240 ft NW of the existing shoreline in 2 to 6 ft of water (Reed, 2011; Figure 5). The structures consist of metal rebar designed to hold recycled oyster shell at a vertical level to allow water flow and promote healthy growth of new spat settlement. They are expected to provide shelter to the area landward, allowing for success of a newly planted salt marsh in the area (City of Gulf Breeze, 2007). For Phase 2 of the project (completed in 2011), a breakwater composed of EcoSystems wave attenuators was placed west of Deadman's Island (Artificial Reef Ecosystems, 2011). An additional phase to the project, consisting of the construction of two additional sections of EcoSystems breakwater totaling approximately 200 ft in length on the eastern end of the existing ReefBLK breakwater, was proposed by the City of Gulf Breeze and completed in 2011 (Figure 5). The applicant proposed to backfill approximately 219,000 square ft of bay area behind the breakwater with 16,000 cy of material from previously identified dredged material disposal sites. Woodland Bayou would be the primary source, and if there is insufficient sediment available, the disposal site at Gilmore Bayou would be used. The outer edges of the fill area are proposed to be planted with emergent wetland vegetation and the center left open for bird nesting. Seagrass restoration and expansion is also proposed for a portion of the remaining submerged area behind the breakwaters (USACE, 2011).

Figure 5. Aerial view of ReefBLK breakwater and EcoSystems wave attenuators placed to the north and west of Deadman's Island (from Deadman's Island Restoration Website, image date September 28, 2011).

The Deadman's Island Restoration Project has received funding from and established partnerships with numerous Federal, State, and local agencies, including a grant from the Army Corps of Engineers' Estuary Restoration Act (ERA). The grant addresses five project tasks: breakwaters, erosion and shoreline stabilization, island wetland creation, seagrass restoration, and bird habitat. The ERA focuses on promoting the restoration of estuarine habitat; developing effective partnerships within the Federal government and private sector; providing Federal assistance for and promoting resourceful financing of estuary restoration projects; and developing and improving monitoring, data sharing, and research capabilities. A 5-year monitoring plan was established for the Deadman's Island project, which includes measurements of basic biological parameters in addition to observations regarding water quality, benthic habitat, fish habitat, oyster spat settlement, accretion and impacts on the environment, and effects on the shoreline to reduce erosion (Reed, 2011).

Project Outcomes

When completed, the Deadman's Island Aquatic Ecosystem Restoration Project is expected to provide protection to Deadman's Island and shallow waters north and west of the island from erosional forces within Pensacola Bay. The reduction in wave energy afforded by breakwaters is expected to provide for creation and re-establishment of salt marsh in the region, improving habitat and water quality for numerous flora and fauna species. Exposed cultural resource sites in the project area also are expected to be protected through the placement of fill material.

RSM Principles Applied

Application of RSM principles throughout the Deadman's Island Aquatic Ecosystem Restoration project is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* Material that had been previously dredged from the mouths of nearby bayous for boating access was included in the restoration planning process as a source of sediment for marsh creation/restoration and protection of cultural resources at Deadman's Island.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* Sediment from existing dredged material disposal sites is being used to restore/create beach and marsh habitat. Previously dredged sediment is being returned to the natural coastal system to restore habitat.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* The restoration project includes participation of multiple agencies and organizations, including the USACE, Florida Department of Environmental Protection, City of Gulf Breeze, and other local organizations.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* Offshore breakwaters were constructed to dissipate erosional wave energy in the project area, and the nearshore area inside breakwaters is expected to be filled with sediment and planted with compatible plant species. In addition, the northern spit of Deadman's Island has undergone plantings to help stabilize the shorline. These methods of restoration are less disruptive to littoral processes than fortifying shorelines on the north and west of Deadman's Island with stone or other hardening materials.

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Part of the Deadman's Island Restoration Project is to use material dredged from the mouth of nearby bayous and existing dredged material disposal sites to protect and enhance the coastal region of Deadman's Island. Although the project has no opportunity to integrate sediment management from river to coastal systems, recognition of the value of sediment from existing dredged material disposal sites and future dredging operations at nearby entrances illustrates an integrated sediment management approach toward beneficial use.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale.* A monitoring plan was established for the Deadman's Island project that included both biological and environmental monitoring. Tracking efforts of monitoring activities is critical follow-up for assessing project effectiveness and applying adaptive management strategies to improve project performance.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* The Florida Department of Environmental Protection performed an investigation to better understand the sediment characteristics and transport processes in the project area. This was valuable information for evaluating and selecting appropriate borrow areas.

Lessons Learned and Recommendations

Substantial sediment is available from existing dredged material disposal sites that should be given serious consideration when restoring/creating marsh habitat. Grain-size analyses and comparison with sediment located in the project area and potential borrow sites provide information needed to identify a compatible restoration borrow source. Choosing a borrow-site location that is updrift of the project location can assure better compatibility of sediment. Future dredging in the bayous adjacent to the project site is expected to provide periodic nourishment material for the Deadman's Island project area.

Perdido Pass Post-Ivan Dune Restoration

Project Site Location

Perdido Pass is a natural tidal inlet located between the mainland peninsulas of Florida Point on the east and Alabama Point on the west in Orange Beach, Alabama, about 30 mi east of Mobile Bay (Figure 6). Prior to stabilization by jetties, Perdido Pass was unstable and migratory, resulting in erosion to the west and accretion to the east of the inlet. The principal cause of inlet migration was westward littoral drift, the volume of which exceeded the capacity of natural processes to transfer sand across the inlet (H. Doc. 274, 1955). Perdido Pass provides access between the Gulf of Mexico and Perdido Bay, a drowned river valley covering an area of approximately 27,200 acres, which is fed by the Blackwater and Perdido Rivers and by several other small, nonsilt bearing streams (S. Doc. 94, 1964). The Gulf shore in this region has low mainland bluffs composed of erodable

Figure 6. Location diagram for Perdido Pass and adjacent beaches.

materials that have supplied large quantities of sand to the shore, resulting in embayments separated from the Gulf by extensive barrier beaches. The barrier beach across Perdido Bay is about 9 mi long, broken only by Perdido Pass. In the vicinity of Perdido Pass near-surface sediments were deposited as marine and estuarine terraces of late Pleistocene age (Browder, Reilly, and Olsen, 2006). In western Florida, the Pamlico sand formation is about 20 ft thick and composed of pure quartz sand with some shell (H. Doc. 274, 1955). Littoral transport processes slowly erode sand from this formation and transport it downdrift toward the project site location.

The Gulf State Park Florida Point area is a natural beach system east of the pass. Prior to Hurricane Ivan, this region had wide beaches and developed dune fields with 15-ft crest elevations and was abundantly vegetated with sea oats and other native plants. Florida Point is designated as a critical habitat for several federally protected species, including the Perdido Key beach mouse, piping plovers, least terns, and nesting sea turtles (Parson *et al.*, 2006).

Tides in the area are diurnal, and the mean range in the Gulf opposite Perdido Pass is estimated to be 1.1 ft and in the bay, 0.5 ft. Primary wave action is from the SE, and the predominant direction of littoral drift in this locality is from E to W, with net westard movement of about 240,000 cy annually (Basille, 1975; Byrnes, Griffee, and Osler, 2010). Historical westward migration of the inlet is evidence of net westward littoral sand transport (Douglass, 2001).

Project Description

The Perdido Pass navigation project was authorized by the 1965 River and Harbor Act and was completed in March 1969 (ARCE, 1966, 1969; Sargent, 1988). The project includes a channel 12 ft deep, 150 ft wide, and approximately 1300 ft long from the Gulf of Mexico into the inlet, including a deposition basin. North of the entrance, the channel is 9 ft deep, 100 ft wide, and approximately 2200 ft long to the Alabama Highway 182 bridge (Figure 7). At the bridge, the channel branches into two 9 ft deep by 100 ft wide channels, of which the Terry Cove channel extends approximately 3400 ft into the northern portion of Terry Cove and the Bayou St. John channel extends approximately 3400 ft into the southern portion of Perdido Bay. Two jetties protecting the entrance extend into the Gulf of Mexico with top elevations of six ft mean low water spaced 600 ft apart at the seaward end (Sargent, 1988). The east jetty contains a low weir section 600 ft long to permit the passage of littoral drift into a dredged material deposition basin 800 ft wide by 1200 ft long, located between the east jetty and the navigation channel (Figure 7). This aids in sand-bypassing for the area (USACE, 2009). During structure design it was recognized that if the inlet was stabilized by jetties, the plan must include a dredging program to prevent deterioration of the channel and supply material to the downdrift shore (Sargent, 1988). The project was designed to stabilize Perdido Pass without negative impact to the Albama Point shoreline west of the pass.

It is estimated that about 250,000 cy of sand are removed from the channel below the Alabama Highway 182 bridge on an annual basis (USACE, 2009). There are seven previously approved disposal areas near the entrance, as well as RSM Disposal Area 8 (Figure 7). Disposal Area 6 is located on the western end of Florida Point for the purpose of stabilizing the sand-dike portion of the east jetty, seaward of dunes and vegetation. Placement here is also necessary to prevent erosion of the shoreward end of the east jetty and to preserve its structural integrity. Disposal Area 2 is located immediately east of the west jetty and extends the entire length of the jetty. Placement in this region is completed to prevent scouring along the structure. Disposal Area 7, which is approximately 10 acres, is located adjacent to and west of the west jetty for the purpose of reducing shoreline erosion, preventing undermining of the jetty and preserving the structural integrity of the jetty. Disposal Area 1 is a 115-acre nearshore open-water disposal area that extends from a point just west of the west jetty between the 7- and 20-ft depth contours extending westward approximately 5000 ft. Disposal in this area results in sand remaining in the littoral system west of the pass.

RSM projects for the Perdido Pass area strive to beneficially use sand dredged from the navigation channel. Since 1970, approximately 7.2 million cy of maintenance material has been removed from Perdido Pass navigation channels and placed into approved disposal sites. According to Sabol, McKinney, and Lillycrop (2009), disposal-site placement has resulted in sandy material removed from the littoral system or placed in areas resulting in a slow return to the system. Dredging records indicate that most sand dredged from the deposition basin and main channel has been placed in the littoral zone on beaches within several hundred yd of the west jetty (Area 7) or immediately offshore of these beaches (Area 1). As such, the beach in this area has grown significantly wider since 1970, suggesting that sand is not being transported westward as rapidly as expected.

In 2003 the Corps conducted an RSM dredging and disposal demonstration project to improve sand-bypassing efficiency by placing dredged material further downdrift (west) of the pass. From January 17 to May 9 approximately 416,000 cy

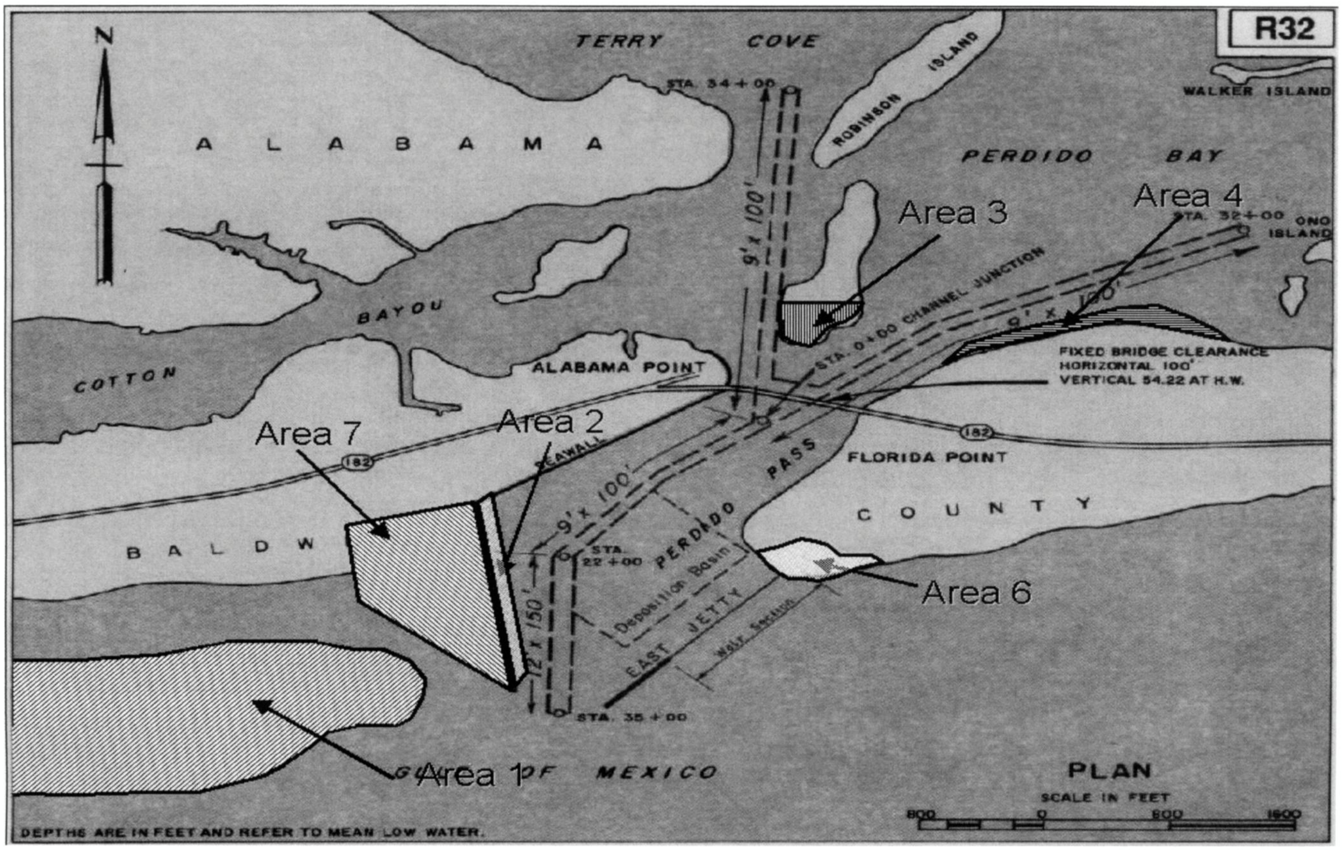

Figure 7. Authorized channel dimensions and disposal areas for the Perdido Pass project (from USACE, 2009). Disposal Area 8 (not included in the figure) extends along the beach 3 mi westward from DA 7.

of material were removed from Perdido Pass channel and impoundment basin. In addition to sand placement in Disposal Area 6 on the northern section of the east jetty to inhibit flanking (56,000 cy), about 103,000 cy were placed in an eastern demostration site west of the west jetty (Figure 8; Mobile District O&M). This was a 410-ft westward expansion of the existing Disposal Area 7 (Gravens, 2003). Placement also included about 257,000 cy in a western demonstration site extending from 0.75 to 1.25 mi west of the west jetty (Figure 8; Mobile District O&M; Sabol, McKinney, and Lillycrop, 2009).

The western site was the main demonstration site and was chosen to improve the placement of sediment in a manner that would promote increased sand transport to downdrift beaches (west of Perdido Pass) by placing sand beyond the influence of ebb-shoal processes to minimize the return of material toward the navigation channel, potentially reducing future maintenance dredging (Sabol, McKinney, and Lillycrop, 2009). Sand was placed below mean high tide due to problems obtaining easements (Ferraro, 2005a). A monitoring plan, including wave and water level measurements, beach profile surveys, hydrographic surveys, and aerial photography, was established to examine the behavior and movement of sand placed downdrift of Perdido Pass (Sabol, McKinney, and Lillycrop, 2009). Placement in the western site was effective at sand bypassing, but due to the placement below mean high tide a large shallow shelf developed along the shoreline. Ponding, "soft spots," and other problems resulted as well, making placement methods impractical from a public relations/public safety perspective. Taking lessons learned from the demonstration project into account, a new disposal area (DA 8) was proposed and would extend from the +5-ft elevation seaward for 3 mi west of DA 7 (Ferraro, 2005a). This new disposal area, which allows for effective sand bypassing at

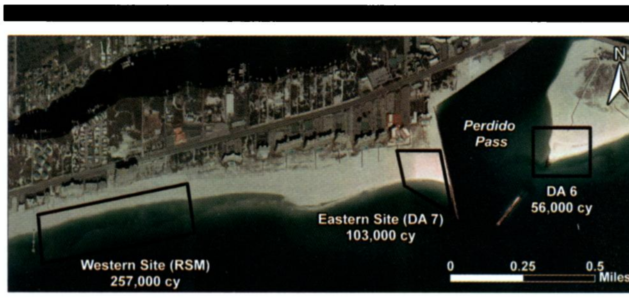

Figure 8. 2003 dredged material placement, including eastern and western RSM demonstration sites.

Figure 9. Florida Point sediment changes occurring around the time of Hurricane Ivan (from Parson *et al.*, 2006).

the project, was used for the first time from December 2005 to January 2006 (ADCNR, 2006).

On September 16, 2004, Hurricane Ivan, the strongest and longest tracked tropical cyclone of the 2004 Atlantic hurricane season, made landfall 20 mi west of Perdido Pass as a Category 3 hurricane with 120 mph maximum winds (Sabol, McKinney, and Lillycrop, 2009). Storm surge resulting from Ivan severely damaged the Florida Point area of Gulf State Park. Large quantities of sand were displaced from the dune fields of Florida Point and transported offshore, eroded from the shorelines of Perdido Pass, and deposited on the north side of Alabama Highway 182 (Ferraro, 2005b). Five to 10 ft of beach dune elevation were lost, critical habitat was destroyed, and there was extensive shoreline recession (Parson *et al.*, 2006). Dunes anchoring the eastern end of the east jetty were breached, and the jetty was damaged. The weir section also was damaged, and this allowed sand to bypass into the deposition basin (Goss, 2005).

Emergency dredging operations were required, including dredging the navigation channel and deposition basin and dredging an access channel along the eastern jetty so a barge could conduct repairs. This resulted in a larger than usual amount of beach-quality sand being dredged without enough disposal capacity within the designated disposal areas (Ferraro, 2005b); however, DA 8 was not yet certified for use as a disposal site (Ferraro, 2005a). As such, the U.S. Fish and Wildlife Service, Daphne Field Office, approached the Corps and the Alabama Department of Conservation and Natural Resources and made the request to use the dredged sand to rebuild dune habitat on Florida Point. This led to multiagency meetings between the U.S. Fish and Wildlife Service, Albama Department of Conservation and Natural Resources, Alabama Department of Environmental Management, Gulf State Parks, City of Orange Beach, and the USACE to develop a restoration plan (Ferraro, 2005b). The final plan involved rebuilding the dunes and dune ridges to pre-Ivan conditions using prestorm surveys as a guide (Goss, 2005).

In mid-January 2005, approval from the Alabama Department of Conservation and Natural Resources to conduct the project was granted by Commissioner Barnett Lawley to the Corps of Engineers. The Corps began dredging in early February 2005 and finished at the beginning of March, with habitat restoration proceeding shortly thereafter (Ferraro, 2005b). The cutterhead dredge *E. Stroud* dredged Perdido Pass, and approximately 560,000 cy of sand was pumped through a 24-in pipe onto Florida Point (Figure 9; Parson *et al.*, 2006). As the material dried, earthmovers spread sand to restore the beach and dune system. Restoring the base elevation involved merging with the existing dune line at about +10-ft elevation, extending the berm seaward with a gradual slope to prevent the formation of escarpments and to maintain a beach that facilitates sea turtle nesting and establishing the prestorm position of the high-water shoreline. Dune restoration was designed to mimic natural dune fields to promote dune growth and formation (Ferraro, 2005b). Dune stabilization measures also were applied, including planting natural dune vegetation and placement of sand fencing (Parson *et al.*, 2006).

As an important note, the emergency situation created by Hurricane Ivan added efficiency to the restoration process. Dredging and restoration time constraints precluded the preparation of standard environmental assessment and monitoring plan reports that typically follow a situation where sediment is placed outside of designated disposal areas. As such, the project was designed and completed with little delay and has been very effective.

Project Outcomes

By May 2005, only a couple months after completion of the restoration effort on Florida Point, natural vegetation was returning, least tern and black skimmer nests were observed, and one sea turtle nest was documented (Parson *et al.*, 2006). While emergency dredging in the Perdido Pass channel reestablished safe navigation at the entrance, placement of dredged sand for dune restoration recreated critical habitats for multiple plant and animal species at Florida Point and provided a sand placement area (PA) for the larger than usual amount of dredged material following Hurricane Ivan. The restored dunes and wide beach are expected to provide storm protection to coastal areas; structural support for the jetty weir, which is critical to sand bypassing to downdrift beaches; and enhanced recreation and tourism for the region. Project implementation was very efficient, solving multiple sediment issues in a short period of time with a dredging cost of about $750,000. The collaboration effort of all agencies saved time and taxpayer funds (Goss, 2005). Resources also were saved by reducing rehandling of sediment.

There are no apparent missed opportunities for efficient use of dredged material. In fact, the emergency nature of the project provided unexpected opportunities for efficient collaboration among Federal, State, and local resource agencies. Had standard regulations and operating procedures been required for this project, costs would have been greater and the time to project completion would have been longer. In fact, project approval at some later date would have resulted in different placement alternatives because emergency dredging was required immediately. This means that the source of sediment for proposed restoration likely would have been different than that used for the emergency restoration. Project flexibility was critical for project success.

RSM Principles Applied

Application of RSM principles throughout the Perdido Pass Post-Ivan Dune Restoration project is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* Material dredged from Perdido Pass after Hurricane Ivan was the direct result of beach erosion along Perdido Key and at Florida Point, a connection directly observed by all resource agencies. Emergency channel dredging was required to maintain safe navigation through the federally authorized entrance. Sand from the entrance channel was recognized as a valuable resource that could be used to restore the coastal habitat from which it was derived. Fast thinking and cooperation among agencies resulted in a well-planned, cost-effective restoration effort.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* Emergency channel dredging after Hurricane Ivan provided an opportunity to place sand eroded from the beach and dunes at and east of Florida Point for habitat restoration. Resource managers recognized the value of restoring sand deposited in Perdido Pass to its natural prestorm location, as well as protecting the inland portion of the east jetty during beach and dune habitat restoration.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* Coordination among Federal, State, and local coastal resource managers was key to successful implementation of the Florida Point restoration. The emergency nature of channel dredging in Perdido Pass provided the motivation for multiagency coordination that promoted effective project execution in a short time period where all agencies benefited. Previous RSM activities in the area (designation of Disposal Area 8) enhanced project perfomance because professional relationships had been established that contributed to efficient project design and operations.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* Efficient coordination among Federal, State, and local resource managers promoted decision making that addressed local resource impacts without adversely impacting the regional transport system. Beach and dune sand deposited in the channel resulting from storm waves and currents likely was derived from beach deposits at and east of Florida Point. Habitat restoration at Florida Point was the primary objective (local need), but placement of littoral sand eventually will be deposited on downdrift beaches when it is removed from the deposition basin adjacent to the east jetty during channel maintenance activities (regional need).

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Not applicable for this project.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at local and regional scale.* It is not clear that a defined monitoring effort has been implemented as part of the project.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* The technical knowledge of resource managers was applied during design and implementation of the Florida Point project, particularly as it related to storm sediment transport dynamics (regional) and habitat restoration (local). As an example, the U.S. Fish and Wildlife Service provided knowledge for critical habitats, coordination for threatened and endangered species, and restoration and creation of lost habitats. Prehurricane beach surveys of the Florida Point area were available and used in the reconstruction of beach and dune habitat.

Lessons Learned and Recommendations

Establishment of RSM workgroups among resource managers and stakeholders builds working relationships that lead to more efficient communication for implementing RSM projects. As with the Florida Point project, coordination among Federal, State, and local resource managers provided effective solutions for managing sediment removal (emergency channel dredging) and placement (poststorm habitat restoration) within the context of local and regional sediment dynamics. Proper technical knowledge of an area is critical for implementing RSM principles, but proper communication is key to recognizing opportunities for project coordination.

The availability of sediment information, such as surveys and sediment budgets, is critical for implementing RSM projects. This was particularly true for the Florida Point project, where project implementation was on a fast track due to the emergency nature of channel maintenance dredging resulting from Hurricane Ivan. The availability of the pre-Ivan survey data sets was vital to habitat restoration because it provided a template for reconstruction of dunes and beach shape. Although various survey data sets were available for assessing sediment dynamics and habitat characteristics, recent technical reports for the area were not available for providing a synthesis of RSM data associated with Perdido Pass and adjacent beaches (*e.g.*, dredging records, shoreline changes, sediment budget). This kind of technical information would be useful for resource managers, particularly as it relates to RSM principles.

Beneficial use of dredged material via RSM principles should be a primary activity for all authorized navigation projects where channel dredging is required. Some disposal areas associated with Perdido Pass were designed to protect jetty structures and, therefore, protect navigation through the pass. For the Florida Point project, beneficial use of

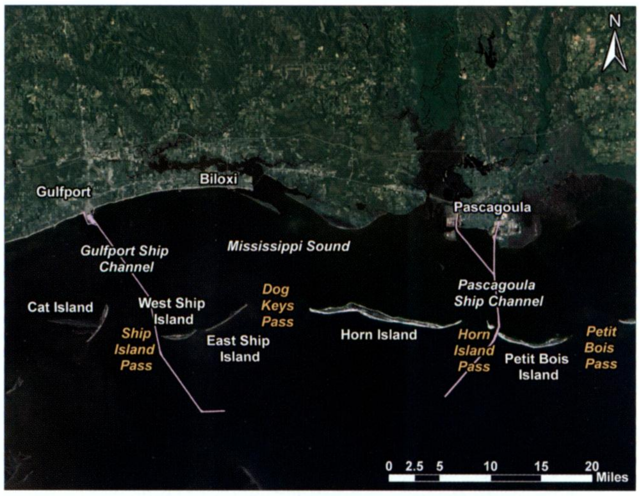

Figure 10. Location diagram for Mississippi Barrier Islands.

sediment was for habitat reconstruction, although the east jetty was protected by the beach sand placement as well. Sand placement downdrift of the jetties (Disposal Areas 1, 7, and 8) is another beneficial use for maintaining littoral transport continuity on either side of the entrance. Application of RSM principles focuses attention on all aspects of sediment dynamics, engineering considerations, and habitat characteristics that results in effective understanding of regional and local system interactions, a requirement for effective coastal resource management.

Mississippi Coastal Improvements Program (MsCIP): Barrier Island Restoration

Project Site Location

Four Mississippi barrier islands form the offshore boundary of Mississippi Sound approximately 10 mi south of the mainland coast of Mississippi, including four permanent passes between the islands (Petit Bois Pass, Horn Island Pass, Dog Keys Pass, and Ship Island Pass). From east to west, the barrier islands are Petit Bois, Horn, Ship (East and West), and Cat (Figure 10). Tidal passes promote exchange of sediment and water between marine waters of the Gulf of Mexico and brackish waters of Mississippi Sound and interrupt the net flow of littoral sand to the west. Petit Bois Pass is about 5 mi wide, with a poorly developed channel and system of shoals. Horn Island Pass is approximately 3.5 mi wide and is occupied by the Pascagoula Ship Channel with a regularly maintained channel depth and width. Dog Keys and Little Dog Keys Passes separate Horn and East Ship Islands as two entrance channels with well-developed ebb shoals (about 6 mi between the islands). Ship Island Pass exists along the western end of Ship Island and encompasses the Gulfport Ship Channel. Water depths in passes are generally 15 ft or less, except in pass channels where maximum depths range from about 29 to 64 ft. The barrier islands provide the first line of defense for the mainland coast and Sound navigation channels, serving to decrease wave activity in their shadow (*e.g.,* Byrnes *et al.*, 2012).

According to Otvos and Carter (2008) and Otvos and Giardino (2004), the Mississippi Sound barrier islands formed during a deceleration in sea-level rise approximately 5700 to 5000 years ago. At that time, the core of Dauphin Island (Alabama) at its eastern end was the only subaerial feature in the location of the modern Mississippi Sound barrier island system (Dauphin Island is east and adjacent to Petit Bois Island). Sand from east of Mobile Pass (Alabama) was transported west via Mobile Pass ebb-tidal shoals and eastern Dauphin Island, depositing as elongate sand spits and barrier islands fronting Mississippi Sound. Beginning approximately 3500 years ago the Mississippi River flowed east of New Orleans toward Mississippi Sound, creating the St. Bernard Delta (Otvos and Giardino, 2004). Deltaic deposition extended over the western end of the Mississippi barrier island system, west of Cat Island. By about 2400 years ago fluvial sediment from the expanding St. Bernard Delta created shoals as far west as Ship Island (Otvos, 1979), changing wave propagation patterns and diminishing west-directed sand supply to Cat Island. With changing wave patterns and reduced sand supply from the east, the eastern end of Cat Island began to erode, resulting in beach sand transport perpendicular to original island orientation (Otvos and Giardino, 2004; Rucker and Snowden, 1989).

Mississippi Sound is considered a microtidal estuary because its diurnal tide range is only about 1.7 ft (NOAA, 2011). The Sound is relatively shallow and elongate (E–W) with an approximate surface area of 800 square mi (Kjerfve, 1986) and a tidal prism of about 3.8×10^{10} cubic ft. Although tidal currents account for at least 50% of flow variance, the Sound responds rapidly to meteorological forcing, as evidenced by subtidal sea-level variations of up to 3 ft and persistent net currents in the tidal passes (Kjerfve, 1986). The relatively shallow and large area of the Sound creates strong currents in tidal passes between the barrier islands, ranging from 1.63 to 3.3 ft/s and 5.9 to 11.5 ft/s on flood and ebb tides, respectively (Foxworth *et al.*, 1962). In the winter months winds from the same direction and of a sufficient magnitude are capable of lowering water surface elevations in the bays and nearshore from 1 to 2 ft (USACE, 1984). Overall, circulation within Mississippi Sound is generally weak and variable, and the estuary is vertically well-mixed. The Pascagoula and Pearl Rivers discharge fresh water into the Sound at average rates of about 14,700 and 12,800 ft^3/s, respectively (Kjerfve, 1986). However, during floods, peak discharges may reach 106,000 ft^3/s, resulting in variable salinities and sharp frontal boundaries. Meteorological effects during the passage of cold fronts and tropical cyclones can double the strength of tidal currents.

The Mississippi barrier islands experience a low energy wave climate, with average significant wave height at National Data Buoy Center (NDBC) Buoy 42007 (22 nautical mi S-SE of Biloxi, in 46 ft depth) averaging 2 ft and 1.3 ft in the winter and summer months, with associated average peak wave periods of 4 to 3.5 seconds, respectively. Wave transformation modeling by Cipriani and Stone (2001) indicated that breaking wave heights on the barrier islands range from 1 to 2 ft. Waves in Mississippi Sound are fetch- and depth-limited. The Coastal Studies Institute's Wave-Current Surge Information System gage CSI-13 located at Ship Island Pass (23 ft depth) from June 1998 through July 2005 measured an average significant wave height of 0.3 ft and associated average wave period of 2.5 seconds.

The barrier islands are composed of beach sand that is derived from updrift beaches east of Mobile Pass and from ebb-tidal shoals at the entrance. Although Cipriani and Stone (2001) and Otvos and Giardino (2004) stated that offshore sources may provide some sediment to the barrier islands, historical onshore movement of sand from outside the littoral zone was not present along the barrier island system based on sediment budget determinations (Byrnes *et al.*, 2012). Furthermore, Cipriani and Stone (2001) discussed that a well-defined cellular structure exists for each barrier island where little sand transfer exists between islands. However, dredging records at Horn Island and Ship Island Passes (called Pascagoula Bar Channel and Gulfport Bar Channel, respectively) suggest that in-channel filling by littoral sand from adjacent barrier islands is persistent, indicating the potential for transport of sand between islands.

Littoral transport along the islands is predominantly from E to W in response to prevailing winds and waves from the SE. Reversals in longshore transport occur at the eastern ends of the islands, but their impact on net sediment transport is localized and minor relative to dominant transport processes from the SE. Persistent sand transport from the east has been successful at maintaining island configuration relative to rising sea level; however, reduced sand transport toward Ship Island has resulted in increased island erosion and segmentation from tropical storms (Rucker and Snowden, 1989). Byrnes *et al.* (2012) documented changes in island configuration since the mid-1800s, illustrating westward migrating islands and inlets, with greatest island changes along Ship Island where sand supply is limited at the end of the littoral transport system.

Project Description

The 2005 hurricane season, including hurricanes Cindy, Katrina, and Rita, significantly impacted the Gulf Coast region. This series of coastal storms devastated the physical, natural, and human resources of the area. In 2005, U.S. Congress authorized the USACE to initiate two comprehensive planning efforts to develop system-wide solutions to assist the U.S. Gulf Coast in recovering from the devastation of repeated hurricane impacts and to provide greater resiliency toward future storm events. These were the MsCIP and Louisiana Coastal Protection and Restoration (LaCPR) (USACE, 2009).

The *Mississippi Coastal Improvements Program Comprehensive Plan and Integrated Programmatic Environmental Impact Statement* was developed to identify near- and long-term strategies to reduce the vulnerability of the region to a recurrence of similar natural disasters. The purpose of the Comprehensive Plan was to assist in the recovery of coastal Mississippi through a number of projects. On December 30, 2005, the MsCIP was authorized by the Department

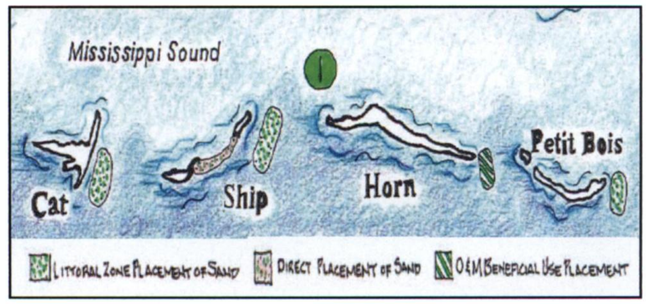

Figure 11. MsCIP Phase 1 Barrier Island Restoration schematic (modified from USACE, 2011).

of Defense Appropriations Act of 2006 (P.L. 109–148) for "Analysis and design for comprehensive improvements or modifications to existing improvements in the coastal area of Mississippi in the interest of hurricane and storm damage reduction, prevention of saltwater intrusion, preservation of fish and wildlife, prevention of erosion, and other related water resource purposes at full Federal expense." The study area consisted of Hancock, Harrison, and Jackson Counties, as well as the offshore ecosystems of Mississippi Sound and its barrier islands (USACE, 2009). On June 24, 2009, Phase 1 of MsCIP, which included the restoration of the Mississippi Barrier Islands, was authorized and funded in Public Law 111-32 (Figure 11; USACE, 2010a).

In an effort to return sand to the littoral system, three measures were adopted: (1) fill Camille Cut with 13 million cy of sand (Figure 12), including loss during placement and the renourishment of some erosion along the north shore; (2) add 5 million cy of sand into the littoral zone area east of East Ship Island; and (3) add 4 million cy of sand to the littoral zone area east of Petit Bois Island (USACE, 2009). Before these proposed plans were adopted as final, a detailed study of littoral transport processes and the long-term sediment budget based on historical shoreline and hydrographic survey data was completed to better direct proposed restoration efforts based on barrier island system response to historical storm and normal conditions. Data on sediment transport pathways and quantities, as well as channel dredging and placement records that document the movement of littoral

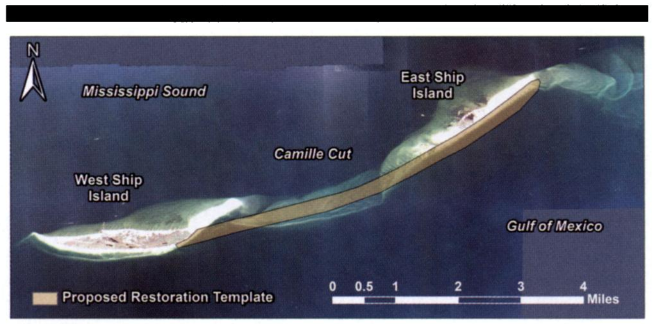

Figure 12. Proposed beach restoration footprint for Camille Cut and East Ship Island.

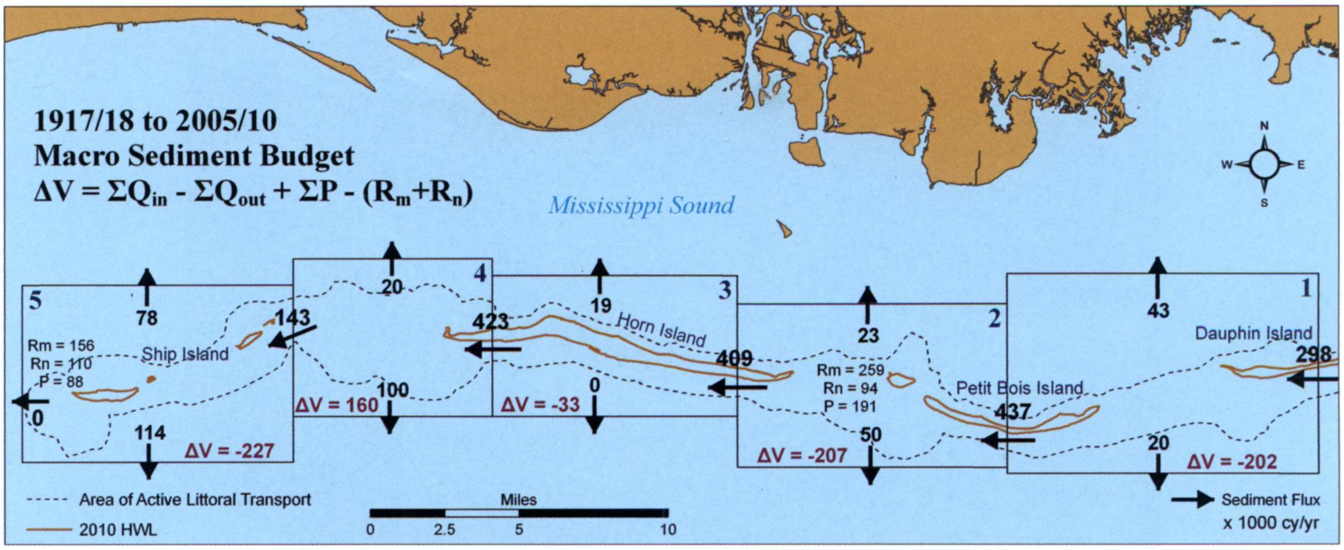

Figure 13. Macro sediment budget for the Mississippi barrier islands (from Byrnes *et al.*, 2012); P is dredged material placement, R_m is sediment removal associated with maintenance dredging, and R_n is sediment removal associated with new work dredging.

sand via channel maintenance, were used to establish the most effective island and littoral zone restoration strategies throughout the barrier island system.

Based on the detailed sediment budget results of Byrnes *et al.* (2012), it was determined that island restoration efforts would be focused on the most vulnerable part of the system relative to historical erosion trends along the islands and sedimentation trends in the passes (Figure 13). As such, proposed placement of sand in the littoral zone near the east end of Petit Bois Island was abandoned in lieu of increased sand placement along East Ship Island (see Byrnes *et al.* [2012] for details). Presently, restoration placement designs are being developed for adding approximately 17 million cy of sand to the island and littoral zone of Ship Island using sand from offshore borrow sites and Disposal Area 10 adjacent to Horn Island Pass (beneficial use of dredged material). When completed, this effort will represent one of the largest beach habitat restoration projects undertaken while using the underlying principles of RSM.

Presently, the West Ship Island North Shore Restoration Project is underway as part of MsCIP. The ecosystem restoration project comprises approximately 77 acres and involves restoring a portion of West Ship Island by placing sand along approximately 9800 ft of the northern shoreline (Figure 14). About half the sand will be placed in a narrow band along the existing shoreline, including the beach area immediately adjacent to Fort Massachusetts, and the other half will be used to fill in the concave area west of the Fort. Two borrow areas with a combined total of 608,000 cy of sand have been identified for the project: (1) the bar channel portion of the Gulfport Harbor widening project and (2) a segment of the old Gulfport Harbor channel that was abandoned in the 1990s when the navigation channel was relocated to the west. Both sources would comprise beneficial use of dredged sediment. Of the material dredged as part of the Gulfport Harbor channel-widening project, the sand portion has been placed in a portion of the old Gulfport Harbor channel until the restoration site is ready for placement (Fall 2011). That portion of the abandoned channel adjacent to West Ship Island acts as a sediment trap for sand moving west from the tip of the island. Sediment in the abandoned channel is derived from west-directed littoral transport and thus is compatible for restoration on Ship Island. The National Park Service has used this area as a source of sand to nourish the beach near Fort Massachusetts several times in the past (USACE, 2010b).

Project Outcomes

The MsCIP barrier island restoration project is planned for construction during Fiscal Year 2013, so project outcomes are a bit premature. However, expected outcomes consist of improved water quality north of Ship Island, beach and dune habitat restoration, and enhanced mainland protection from storm and normal waves and currents (Rees, 2010). Furthermore, all restoration efforts under MsCIP are applying the principles of RSM, including beneficial use of dredged material, when planning, designing, and constructing coastal restoration projects. After completion the Phase I Comprehensive Plan expected performance for barrier island restoration includes \$20 million annual damages avoided, \$43 million annual fishery losses avoided, 1150 acres restored, and 4900 jobs created (Rees, 2010).

RSM Principles Applied

Application of RSM principles for the MsCIP Barrier Island Restoration is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.*

Figure 14. Approximate fill limits for West Ship Island North Shore Restoration (from USACE, 2010b).

Substantial resources have been devoted to developing a clear understanding of sediment transport pathways and quantities for the Mississippi barrier islands and entrances, channel dredging quantities and placement practices for littoral sand deposited in the channel, and the sand budget throughout the system relative to areas of greatest restoration need. An operational sediment budget has been developed for the area because Federal, State, and local stakeholders recognize the value of sediment as a resource for habitat restoration.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* All aspects of restoration efforts under MsCIP, including the barrier island restoration project, have embraced the RSM practices and procedures when designing habitat restoration projects. Channel dredging operations have been scrutinized to identify better methods for using dredged sediment for beneficial use. Littoral sand dredged from Horn Island Pass channel and deposited in Disposal Area 10 adjacent to the channel is expected to be an important source of sediment for habitat restoration on Ship Island.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* Dozens of Federal, State, and local project partners meet on a monthly basis for project updates and questions. All partners have an opportunity to review and comment on all study and design aspects of restoration projects.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* Alterations to original habitat restoration designs for the barrier islands were implemented based on detailed anaylses of coastal process and survey data sets. Knowledge gained through these analyses direct changes for initial designs to be more efficient with funds and sediment resources toward optimal restoration design. This includes evaluation of potential regional impacts of proposed restoration actions.

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* All dredging projects in the Mobile District strive to use dredged material for environmental restoration and economic benefit. This includes potential sand resources from river channel dredging within the District. Although river sand was evaluated as a potential borrow source for island restoration, it may not be the best alternative for this project. The fact that river sand is being considered as a source for coastal restoration indicates the importance the District places on an integrated systems approach to management of sediment throughout the system.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale.* Project monitoring is a requirement for all MsCIP projects, including the barrier island restoration that will be conducted along East and West Ship Island, Mississippi.

Figure 15. Location diagram for Deer Island, Mississippi.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* A detailed report on coastal processes, sediment transport pathways and quantities, and an operational sediment budget derived from historical survey data was completed so restoration design and construction would be based on sound technical knowledge (see Byrnes *et al.*, 2012). Furthermore, numerical modeling studies of proposed sand borrow and placements geometries have been conducted to ensure adverse impacts do not result as a consequence of restoration. All study efforts are aimed at improving management of sediment.

Lessons Learned and Recommendations

Initial construction for the MsCIP barrier island restoration project is planned for Fiscal Year 2013, so there are no specific lessons learned as yet. However, the information gained from detailed analysis of coastal processes data sets, including historical survey data sets, have proven invaluable for documenting sediment quantities and movement throughout the barrier island system. Knowledge gained from these analyses has been used directly to refine restoration design and placement. If at all possible, an operational sediment budget (based on survey measurements) should be developed for all habitat restoration projects where proposed actions are expected to have an impact on regional sediment transport.

Deer Island Restoration: Beneficial Use of Dredged Material

Project Site Location

Deer Island is a 4.5-mi-long island off Biloxi and Ocean Springs, Mississippi (Figure 15). The island is not a barrier island but a relic of the mainland with a solid foundation cored by late-Pleistocene beach ridges similar to the coastlines in Harrison County and part of Jackson County (Schmid and Otvos, 2003).

The most prominent geologic formation on the Mississippi coast is the Gulfport Formation: a regressive sand unit deposited during the highest sea-level stage of the Pleistocene. This deposit forms the high ridge along the Harrison County coast upon which the cities of Pass Christian, Long Beach, Gulfport, and Biloxi have been constructed. Due to rising sea level and subsequent beach erosion during the Holocene, Gulfport Formation beach ridges have retreated to the present mainland shoreline, leaving ancient shoreline remnants such as Round Island in Jackson County and Deer Island in Harrison County (Jacobson and Rees, 2006). The geologic framework of Deer Island consists of Gulfport Formation ridges with estuarine Biloxi Formation and alluvial Prairie Formation deposits. These deposits formed bluffs on the carved Biloxi River valley during the Wisconsin glacial lowstand. Before and during the recent rise in sea level, a series of Holocene fresh and brackish water sediments were deposited. The buried Pleistocene land surface has a SE slope underneath the island, and at lower elevations, mud, sand, and peat cover the Pleistocene surface (Schmid and Otvos, 2003). Areas where the island's core is outcropping are evident by trees and marsh, whereas regions where the core is buried are marked by shoreline erosion (Rankin, Schmid, and Gaffney, 2005). As such, shoreline erosion is most prominent in the SE region of Deer Island where Holocene muddy sands and marsh deposits form the shoreline. The geology of Deer Island is an important factor in understanding how it experiences erosion (Schmid and Otvos, 2003).

On the offshore of Deer Island, average wave heights historically have been less than 3 ft, with the largest waves occurring between September and November. Based on historical water level data, the region is highly sensitive to storm surge, and it is an important factor shaping present beach configuration. The barrier island system fronting Mississippi Sound affords some protection from offshore waves. Tides in the area are diurnal with an average range of about 1.5 ft; net flows are predominantly directed toward the west. Westward longshore transport is evident by deposition of sediments on the eastern side of headlands along the south shoreline of Deer Island, previous growth of the spit on the westernmost end of the island, and the extensive sand shoal located to the SW of the island. Sediment sources to Deer Island include fine-grained sediment from Biloxi Bay, which is fed by the Tchoutacabouffa and Biloxi Rivers, and erosion of the island itself. There is a sand deficit in the littoral system, making the island prone to erosion (Rankin, Schmid, and Gaffney, 2005). Deer Island does not have an updrift sand source to replenish sediment lost during storm events (Mississippi Office of Geology, 1999).

Over the past 150 years, sea-level rise in the region has been about 1 ft: a rate of approximately 0.12 in per year. The loss of sediment due to erosion along the island has exceeded the amount of sediment being deposited on the island. Increased water depth from sea-level rise has promoted deposition on the submerged nearshore south of Deer Island. Sea-level rise also affects the natural beach slope in the area and increases storm surge elevations (Rankin, Schmid, and Gaffney, 2005).

Previously under private ownership, the State of Mississippi purchased the 400-acre Deer Island with assistance from the Coastal and Estuarine Land Conservation Program in 2003, and it became part of the Mississippi Coastal Preserves system. Mississippi Department of Marine Resources (MDMR) Office of Coastal Ecology manages the island with the mission of re-establishing and stabilizing natural habitat represented in the distinct island ecosystems. Deer Island has not been inhabited since prior to Hurricane Camille in 1969. The island provides critical coastal habitats, a base level of storm protection for much of the Biloxi waterfront, and recreation (Ramseur, 2010). Due to the increasing population along the Mississippi coast, this Mississippi Coastal Preserve site provides necessary habitat to various species including osprey, blue herons, and deer. Of the endangered species listed by the U.S. Fish and Wildlife Service for the Mississippi coast, the most likely to be found on or adjacent to Deer Island are the bald eagle, brown pelican, Gulf sturgeon, Kemp's Ridley and loggerhead sea turtles, and the piping plover (Jacobson and Rees, 2006).

Deer Island has experienced about a 30% reduction in area from beach erosion since 1850 (Schmid and Otvos, 2003). Historically, material dredged from the nearby Biloxi Harbor Navigation project, which includes the East Access Channel, Lateral Channel, and West Approach Channel, has been periodically placed on Deer Island as beach nourishment. Multiple sediment management projects have been completed, planned, or are underway for restoration of Deer Island.

Project Description

In 2001 the USACE, in cooperation with the State of Mississippi, began searching for a site where fine-grained material could be placed to restore or create marshlands. The purpose of the project was to create a coastal wetland from dredged material excavated from shipping channels to maintain their depth and side slopes. Final site selection, based on location with respect to channel source material, environmental impact, existing water depth and conditions, available surface area size and shape, construction access and limitations, permitting issues, risk of success, and economics, was an approximate 45-acre region on the eastern side of Deer Island. The Deer Island marsh project was considered a pilot project for larger sites to follow. Project planning required coordination among various agencies, including the U.S. Fish and Wildlife Service, the State of Mississippi Department of Coastal Resources, and local environmental and planning groups. Short- and long-term sustainability goals were established for the Deer Island Marsh Project, as well as specialized reports, which included the following: Implementation Schedule and Construction Sequence Plan, Fill Placement Plan, Water Quality Run-Off Plan, Fill Settlement Monitoring Plan, Dike Breaching and Re-shaping Plan, Plantings and Habitat Development Plan, and a Performance Monitoring and Maintenance Plan (Knott, 2008). Funding came from the USACE with some aid from the State of Mississippi and the City of Biloxi through the Biloxi Port Commission (Wildlife Mississippi, 2003). Project authority was granted under Section 204 of the Water Resources Development Act of 1992 (Ecosystems Restoration Projects in Connection with Dredging; USACE, 2006).

The design, based on extensive modeling, geotechnical investigations, laboratory evaluations, and environmental science analyses, was completed in the fall of 2002 (Figure 16; Knott, 2008). The project included a triangular containment dike that was hardened on the eastern section with rip-rap. The rip-rap was extended into open water off the north end of the dike to form a protective jetty (USACE, 2009). Construction of the dike, which was built with two weir sections and rip-rap structures, was finished in the spring of 2003 and included the placement of about 72,000 cy of sand and 5600 tons of protection stone. Hydraulic filling of about 340,000 cy of sediment dredged from the Biloxi Lateral Channel by the Corps and other nearby locations began soon after and was completed in 60 days (Knott, 2008). The material was allowed to settle for approximately 24 months until the winter of 2005. In February 2005, native plantings were completed in the consolidated material, and habitat development began in the spring (Figure 17; Knott, 2008).

Since completion of the project, the site has been hit with multiple hurricanes. In late August 2005, Hurricane Katrina impacted the Deer Island site with maximum wind gusts of between 90 and 100 mi/hr, storm surge of between 17 and 22 ft, and wave heights exceeding 10 ft (Graumann *et al.*, 2005; Knabb, Rhome, and Brown, 2005). Deer Island absorbed significant energy from the hurricane, resulting in less damage to the mainland. Storm conditions caused additional widening of one of the dike breaches and removal of some material in dike and interior marsh deposits, leaving the elevation too low in some areas to support marsh vegetation (Knott, 2008). Approximately 25% of the dredge material and 50% of the plants were lost. Since then, Coastal Preserves has been working to identify opportunities to use material from local dredging projects to restore the marsh site back to its original project elevation (Coastal Markers, 2009). In March 2011 the USACE completed a berm repair project for the original restoration site along the NE end of the island. Even after storm impacts, the MDMR considers the overall health of the remaining marsh vegetation to be excellent (USACE, 2009).

Funded through the Coastal Improvement Assistance Program (CIAP) to support the beneficial use of dredge material, the Department of Marine Resources Coastal Preserves Program, together with the University of Southern Mississippi Gulf Coast Research Laboratory and the Gulf Coast Conservation Corps, replanted marsh and dune vegetation on the Deer Island Marsh Project site in June 2008. This was completed to help decrease erosion by stabilizing soil in the interior portion of the project that was scoured by high water and intense wave energy during prior hurricanes (Coastal Markers, 2008).

In January 2009 the USACE released a joint public notice regarding proposed maintenance dredging and the discharge of dredged material to restore the Deer Island Marsh Restoration Project. The proposed beneficial-use project included redredging 8900 cy of material from the access

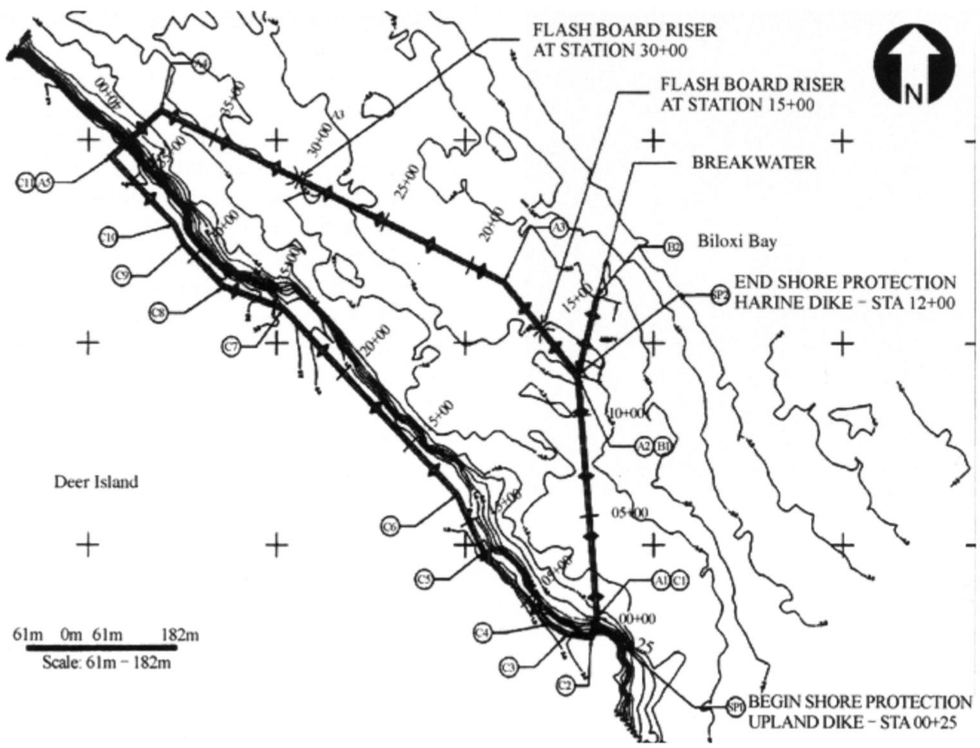

Figure 16. Site design plan for Deer Island Marsh Creation (from Knott, 2008).

channel originally used to construct the project and the discharge of up to 100,000 cy of dredged material from various local projects to restore the marsh to design elevations. An attempt to place dredged material into the marsh site several months prior failed because of inadequate depths/access to the site. The placement of dredged material at this beneficial-use site would be more economical than using upland sites commonly used in the past. The Department of Marine Resources requested sediment containing a higher proportion of sand, if possible, to improve the establishment and survival of certain marsh plants. The goal was to place dredged material as evenly and as far into the project area as possible while carefully minimizing equipment impact to established vegetation (USACE, 2009).

Figure 17. Completed Deer Island Marsh Project (from Ramseur, 2010).

As requested, sandy material dredged from Graveline Bayou in Jackson County was placed in the Deer Island site. This resulted from Coastal Preserves working to identify opportunities to use material from local dredging projects. Consequently, Coastal Preserves, along with State and Federal agencies, and other partners, formed the Beneficial Use Group (BUG) for coastal Mississippi. This group has the goal of ensuring that whenever good quality dredge material is available, it will be used to restore coastal habitat (Coastal Markers, 2009).

The modern Deer Island Restoration Project is part of an ongoing effort to bring Deer Island back to its original size prior to Hurricane Katrina (GOMF, 2010). The project objective is to provide shoreline erosion control and protection by reducing wave action along the shoreline for approximately 50 acres of wetlands/marsh created in 2003 under the Deer Island Marsh Project. As part of the project, a grant was issued by the Gulf of Mexico Foundation (for NOAA) to the MDMR in early 2010 to protect 800 linear ft of shoreline on the NE corner of Deer Island from erosion by creating a breakwater using recycled oyster shells bound in mesh wire bags, which were stacked and staked along the shoreline (MDMR, 2010). The mesh wire bags are expected to degrade, leaving the oyster habitat free of debris. Live oyster seeding was included in 2010 to create a new oyster reef, which is expected to attract fish and create habitat for small marine plants and animals. The breakwater site will be monitored for

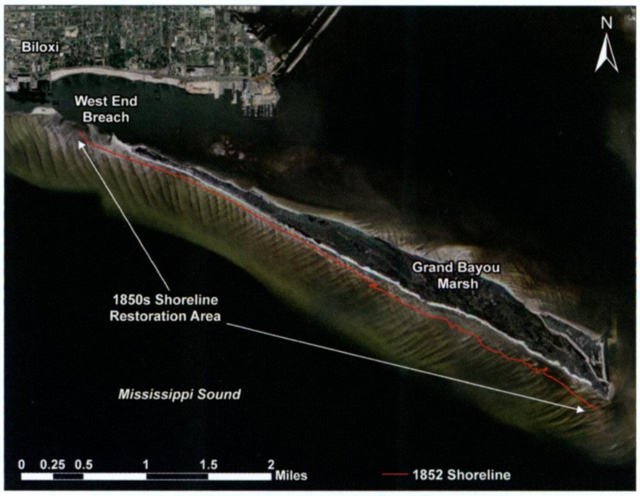

Figure 18. Deer Island Ecosystem Restoration Project sites, including location of the 1852 shoreline.

small oyster recruitment, water hydrology, and erosion control success/retention of the shoreline (GOMF, 2010; MDMR, 2010).

Furthermore, an extensive Deer Island Ecosystem Restoration Project to restore and protect other portions of the island is being constructed as part of the USACE MsCIP. The project was authorized under Section 528 of the Water Resources Development Act of 2000. It includes restoration of three sites: the western breach of Deer Island, the breach at Grand Bayou Marsh, and the overall restoration of the south shore of Deer Island back to its historic 1850s shoreline (Figure 18). Regional sediment management practices, including beneficial use of dredged material and communication between stakeholders, are an integral part of this project (Jacobson and Rees, 2006). Sediment used to restore the island came from maintenance material dredged from the Biloxi West Approach Channel and an offshore borrow area (USACE, 2010). Upon completion, the project, which began with filling the west-end breach in September 2010, is expected to provide productive estuarine wetlands, restore beach and dune habitat, create hard-bottom habitat, reduce coastal erosion, and restore the coastal maritime forest (Ramseur, 2010; USACE, 2010). Furthermore, the restoration is intended to diminish wave energy impacting the mainland coast of Mississippi. As of April 2011, the sand placement phase is complete and the planting phase to revegetate newly restored sites is in progress. An area has been designated at the SE end of Deer Island for future beneficial use of sediment dredged from Biloxi Ship Channel.

Project Outcomes

Restored marsh on the NE side of the island has reduced shoreline erosion along the eastern end of Deer Island by limiting the amount of wave and current energy impacting this portion of the island; substantial new marsh habitat was created as well (see Figure 17). Offshore island marsh creation provided other outcomes, including sacrificial coastal protection to mainland Mississippi from water and wind forces; beneficial use of dredged material from nearby channels/harbors; increased marsh, fish, and bird habitat; and increased coastal recreation, including wildlife viewing and fishing (Knott, 2008). The Mobile District and MDMR have embraced the concept of beneficial use of dredged material and the principles of RSM to restore and create habitat along Deer Island and other locations in coastal Mississippi. All opportunities for beneficial use of dredged material are evaluated for each dredging project. Not only has this process benefited environmental restoration and reduced the need for upland dredged material disposal, but placement of dredged material at beneficial-use sites has been more cost-effective than using upland sites.

RSM Principles Applied

Application of RSM principles throughout the Deer Island beneficial-use projects is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* All coastal dredging projects in the Mobile District strive to use dredged material for environmental restoration and economic benefit. Sediment dredged from channels nearby Deer Island was used to create marsh habitat instead of being placed in open water or upland disposal areas. In fact, placement of dredged material at beneficial-use sites was more cost-effective than disposing in upland sites.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* Deer Island served as an appropriate site for marsh creation. The 50-acre project was a pilot project for using dredged material to create marsh. Lessons learned from this project will be applied to future beneficial-use marsh creation projects.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* Federal, State, and local agencies were involved in the Deer Island beneficial-use projects, including the U.S. Fish and Wildlife Service, MDMR, and the USACE. In addition, collaboration led to the formation of BUG, which is responsible for ensuring that dredged sediment is used for habitat restoration and creation whenever possible. Efficient collaboration among these groups resulted in a successful marsh creation project.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* In the case of Deer Island, the primary source of sediment to the site is fine-grained material. However, the rate at which sediment is eroded from the island exceeds the amount contributing to natural habitat creation on the island. Overall sediment transport at and adjacent to Deer Island is from NE to SW, so material dredged from channels N and E of Deer Island would benefit habitat on the island within the context of the regional sediment transport system. Federal and State agencies recognize this pattern within the Deer Island sediment system and continue to identify uses of dredged sediment for beneficial use.

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Not applicable for this project.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale.* The Deer Island marsh creation project has been monitored since the initial project was completed in 2005. Efforts have been made to repair and maintain the project in response to storm impacts and normal annual changes. Proper monitoring of the site has allowed for a better understanding of local and regional sediment transport processes and the effects of creating marsh habitat. In fact, the USACE is currently building a habitat restoration/shoreline enhancement project along the west end and south side of Deer Island, the design of which has benefited from lessons learned regarding construction and monitoring from the original project.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve the management of sediment.* Geotechnical and coastal engineering plans, as well as an environmental science examination, were crucial for project design, construction, and monitoring the Deer Island beneficial-use project. Project design based on a sound understanding of sediment transport processes, coastal geomorphology and dynamics, and periodic dredging activities relative to extraction and placement quantities and timing for the region led to a successful outcome for habitat restoration/creation on Deer Island.

Lessons Learned and Recommendations

Part of a successful project is proper monitoring and maintenance of the site. Damage to the project site from hurricanes was addressed and appropriate restoration measures were (are being) completed to maintain/enhance all created marsh/shoreline habitat. Storm restoration plans for dike breaching and marsh refilling/planting could save time in the future. Efficient communication among Federal and State agencies, in cooperation with local agencies and nongovernmental environmental groups, has resulted in enhanced project performance. In fact, beneficial placement of dredged sediment from local channels for habitat creation/restoration was found to be more cost-effective than traditional upland or offshore placement. Finally, monitoring of completed projects has and should continue to assist with existing project maintenance and new project formulation. As such, it is recommended that marsh elevation at the 50-acre site on NE Deer Island be closely monitored to ensure that dredged material is placed as necessary to maintain project elevations conducive to marsh growth.

Calcasieu Ship Channel–Sabine National Wildlife Refuge: Beneficial Use of Dredged Material

Project Site Location

The project area is located in the Calcasieu-Sabine Basin within the Chenier Plain of SW Louisiana in Cameron Parish.

Figure 19. Location of Calcasieu Ship Channel and the Sabine National Wildlife Refuge.

The Calcasieu Ship Channel extends 36 mi north from the Gulf of Mexico at Calcasieu Pass along the western side of Calcasieu Lake and through part of the Calcasieu River to Lake Charles (Figure 19). Calcasieu Lake is a drowned river valley that is 16 mi long, varies in width from 5 mi at the north end to 7 mi in the southern region, and has an average depth of 6 ft. Prior to construction of the ship channel, the lake acted as a sink for sediment deposited by riverine discharge from the Calcasieu River (USACE, 2009).

Hydrology of the area is affected by a combination of riverine freshwater inflow, Gulf of Mexico tides, precipitation, and wind effects on water level and directional flow. Strong and prolonged winds from the S and SE result in large volumes of water from the Gulf of Mexico being pushed into Calcasieu Lake, causing water levels in the marshes to rise (Gammill, 2002). Daily tides are primarily diurnal with a spring tidal range of approximately 1.9 ft. Frontal systems affecting the area can create erosive wind and wave conditions across Calcasieu Lake. The velocity of tidal currents in the area affects sediment erosion and deposition. Tidal currents tend to be stronger during ebb tides because fresh water constantly enters the system from Calcasieu River and other sources, and less water enters the Gulf of Mexico during flood tides than is discharged into the Gulf during ebb tides. Average velocities in the lake peak around 3.9 to 4.6 ft/s for ebb tides and 3.3 to 3.9 ft/s for flood tides (USACE, 2009).

Occupying the marshes between Calcasieu Lake and Sabine Lake is the federally managed Sabine National Wildlife Refuge (SNWR; Figure 19). The refuge encompasses about 124,500 acres of marsh, in which 33,000 acres are impounded freshwater marsh and 91,500 acres are brackish to intermediate marsh (USACE, 2009). The SNWR is managed to provide habitat for migratory waterfowl and other birds and for the preservation and enhancement of coastal marshes for wildlife and fish (USDOI and USFWS, 2007).

Much of the intermediate estuarine marshes in and around the SNWR deteriorated to broken marsh and/or open water in

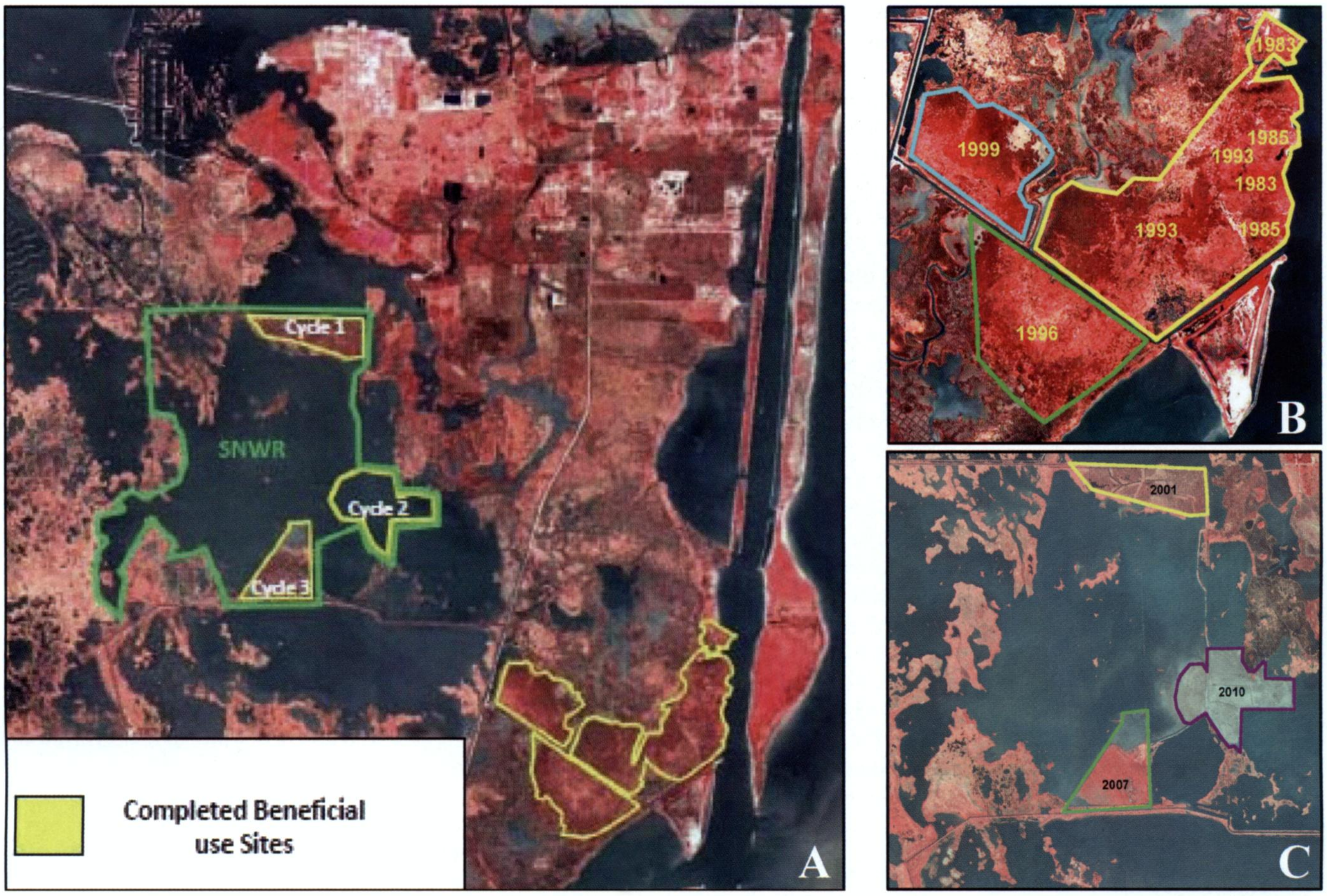

Figure 20. Completed beneficial-use placement areas from 1983 to 2010 in SNWR. A, Overview of site locations in the SNWR; B, Placement areas completed between 1983 and 1999; C, Placement areas completed between 2001 and 2010 (from USACE, 2010).

the latter half of the twentieth century. This has been due to natural subsidence, salt water intrusion from the effects of the Calcasieu Ship Channel, storm damage, and altered hydrology. It is estimated that marshes in the Chenier Plain, including the SNWR, are experiencing an average relative sea-level rise of about 1.13 cm/yr (3.7 ft/century; NOAA *et al.*, 2010). Removal of the bar at Calcasieu Pass in 1874, which acted to constrict saltwater and tidal inflow into the basin, along with subsequent deepening and widening of the navigation channel, allowed increased saltwater and tidal intrusion into Calcasieu Estuary. Channel changes over the past century contributed to marsh loss, tidal export of organic marsh substrate, and an overall shift to more saline habitats in surrounding marsh areas (Gammill, 2002). In the 1980s, in an effort to combat marsh loss, restoration efforts began using maintenance dredging material from the Calcasieu Ship Channel.

Project Description

The first use of dredged material from the Calcasieu Ship Channel took place in 1983, when approximately 20,000 cy of sediment were placed at two sites within the SNWR off the right descending bank of the channel in an attempt to stabilize the bank and restore eroded wetlands. Earthen dikes were constructed only on the channel side of the PA to prevent the flow of dredged material back into the navigation channel. In 1985, material dredged for maintenance of the ship channel was placed in open water areas between the 1983 placement sites (Figure 20). Earthen dikes were constructed the same as in 1983, with additional dikes constructed perpendicular to the channel on the north and south sides of the sites to keep dredged material off the 1983 sites (Creef, 2011). The USACE Operations and Maintenance (O&M) Division, New Orleans District, provided the full Federal share for these projects (USACE, 2010).

Beneficial use of dredged material was again performed in 1993 and was authorized by Section 1135 of the Water Resources Development Act of 1986. Approximately 1,840,600 cy of material removed as part of maintenance dredging from the Calcasieu Ship Channel were placed into the SNWR north of West Cove Canal to restore wetlands. Containment dikes were constructed only along the navigation channel and along the north bank of West Cove Canal. The project was sponsored by the New Orleans District and the State of Louisiana (Creef, 2011).

The New Orleans District received authority and funding from Section 204 of the Water Resources and Development Act of 1992 to place dredged material into the SNWR in 1996 and 1999. The local project sponsor was again the State of Louisiana. In 1996 approximately 1,291,200 cy of material dredged from the navigation channel were placed into the SNWR south of the West Cove Canal (Figure 20). Containment dikes were constructed along the south bank of West Cove Canal and along the east bank of Hog Island Gully. In 1999 approximately 1,394,000 cy of sediment were placed for marsh creation north of the West Cove Canal and west of the 1993 placement project within perimeter dikes constructed to an elevation of +8 ft Mean Low Gulf (MLG) along the north bank of West Cove Canal and on the east and west boundaries of the placement site. In addition, a low-level dike was built to an elevation of +4.5 ft MLG along the northern boundary of the PA (Creef, 2011).

In January 1999 the Sabine Marsh Creation Project (CS-28) was approved by the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) as part of Project Priority List 8. The project consisted of placement of dredged material to create multiple marsh sites in the large open water area NE of Browns Lake, located in the SNWRNational Wildlife Refuge, with annual maintenance dredging material from the Calcasieu River Ship Channel (Figure 20; LCWCRTF, 2010a). The project, which consisted of five cycles, was designed to create approximately 1120 acres of emergent vegetated marsh and to nourish and protect existing broken marsh (Sharp and Juneau, 2007).

Cycle 1 of the Sabine Marsh Creation Project was completed in February 2002. Approximately 834,400 cy of sediment were placed in a 203-acre shallow-water wetlands development site contained by retention dikes in the SNWR (Creef, 2011). Small channels called trenasses were constructed before placement of dredged material at the project site to enhance fisheries and water movement. Cycle 1 was constructed with a temporary pipeline because it was determined to be most cost effective. After the dredged material consolidated the southern containment dike was degraded and breached to allow for water movement and to restore the area to more natural conditions (LCWCRTF, 2010a).

Cycle III of the project was completed in March 2007 and resulted in the creation of marsh east of Browns Lake from about 828,800 cy of dredged material. Earthen dikes were constructed to contain the dredged material, and lower-level earthen overflow weirs were constructed to aid in dewatering of the beneficial-use site and to create fringe marsh with the overflow. After dredged material settled, degradation of the retention dikes took place (LCWCRTF, 2010c).

Cycle II of the Sabine Marsh Creation Project was completed in September 2010. This cycle involved the placement of approximately 1,000,000 cy of material to create approximately 234 acres of marsh. Earthen dikes were constructed to contain the dredged material, and lower-level earthen overflow weirs were constructed to aid in dewatering of the beneficial-use site to create fringe marsh and mud flats with the overflow. Installation of a permanent dredged-material pipeline was completed in February 2010 (CWPPRA, 2011). The pipeline, measuring 3.57-mi long, runs from the Calcasieu Ship Channel to the NE corner of the SNWR and will be used for future marsh creation projects in conjunction with USACE maintenance dredging of the Calcasieu Ship Channel. Cycles IV and V of the Sabine Marsh Creation Project (CS-28) have yet to be completed (LCWCRTF, 2010b).

The monitoring plan for the Sabine Marsh Creation Project (CS-28) includes concurrent monitoring of an appropriate reference area for emergent vegetation monitoring. Marshes west of the project boundary, in the Hog Island Gully Project (CS-23), were chosen based on similar soil type, vegetation, hydrology, and proximity to the project area. Coastwide Reference Monitoring System (CRMS) sites provide valuable information for monitoring the project, such as Surface Elevation Table data, accretion, hourly water level and salinity, and vegetation sampling. Other monitoring elements for the project include aerial photography to document land to open-water ratios and land-change rates, emergent vegetation monitoring along transect lines to document the condition of emergent vegetation in the project area over the life of the project, and elevation surveys within each placement site (Sharp, 2003).

In 2009 the New Orleans District released a Draft Dredged Material Management Plan (DMMP) and Supplemental Environmental Impact Statement (SEIS) for Calcasieu River and Pass to address additional disposal capacity needs (USACE, 2009). The project currently does not have adequate disposal capacity to maintain the navigation channel to authorized depths. Placement options for beneficial use include two sites in the SNWR: (1) Placement Site 5, which has a total capacity of 8,873,500 cy and abuts the project boundary for the CWPPRA CS-28 project; and (2) Placement Site 18, which has the capacity to hold 9,276,500 cy (Figure 21; USACE, 2009).

Project Outcomes

The beneficial placement of material dredged from the Calcasieu Ship Channel into the SNWR since 1983 has resulted in hundreds of acres of restored marsh. Between fiscal year 1983 and 1993, 427 acres of marsh were restored; in 1996, 360 acres; in 1999, 230 acres; in 2001, 162 acres; in 2007, 180 acres; and in 2010, 282 acres (USACE, 2010).

Newly created marsh provides habitat for wildlife, including migratory waterfowl and other birds. In addition, restoration of wetlands reduces further loss of land and serves to create a buffer for storm surge protection of surrounding wetlands (USACE, 2009). Simultaneously, maintenance dredging of the ship channel, which serves as the marine industrial transport corridor from the Port of Lake Charles to the Gulf of Mexico, is completed efficiently (NOAA *et al.*, 2010). It is expected that beneficial use of dredged sediment from the Calcasieu Ship Channel will continue to produce hundreds of acres of restored/created wetlands in the Calcasieu Basin for the foreseeable future.

RSM Principles Applied

Application of RSM principles associated with dredging of the Calcasieu Ship Channel is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.*

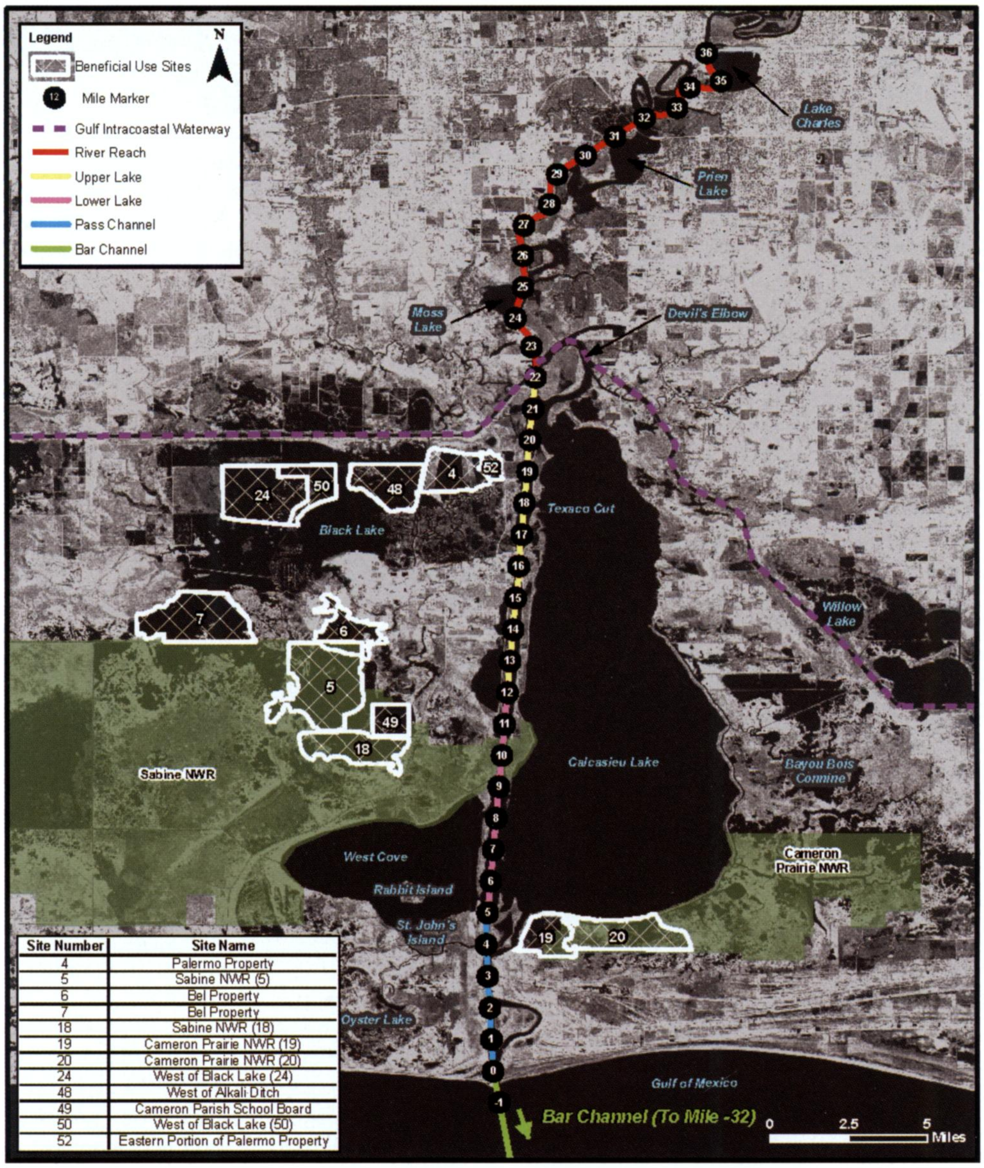

Figure 21. Calcasieu River and Pass Dredged Material Management Plan placement options for beneficial use (from USACE, 2009).

Instead of confining fine-grained dredged material in upland disposal sites along the Calcasieu Ship Channel, as was done prior to 1983, a portion of the material dredged from the navigation channel has been used to create marsh habitat in the SNWR. Wetland restoration of degraded marsh has been ongoing in the SNWR since 1983.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* Management of sediment dredged from the ship channel to maintain authorized dimensions was greatly improved by using dredged material for wetland restoration. Disposal-site capacity is a problem for most inland and estuarine navigable waterways, and wetland restoration provides a mechanism for retaining estuarine sediment within wetlands without requiring offshore or upland disposal.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* Coordination among USACE O&M and local project sponsors (LA Office of Coastal Protection and Restoration [OCPR] and the SNWR) was crucial for optimal timing and beneficial placement of dredged material.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* The decision to use fine-grained dredged material for wetland restoration/creation as opposed to offhsore or upland disposal acknowledges the source of channel deposition and recognizes the value of retaining sediment resources within the marsh/estuarine system. Offshore or upland disposal of dredged material implies limited benefit,

whereas restoring/depositing sediment in wetlands recognizes the local and regional value of the resource.

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Sediment deposited within the Calcasieu Ship Channel from upland sources and erosion of adjacent wetlands was placed into nearby degraded coastal wetlands. This process implicitly recognizes the importance of a sediment budget for developing an integrated sediment management approach.

(6) *Monitor projects to evaluate the physical, environmental, and social· impacts at the local and regional scale.* A 20-year monitoring plan was established for the Sabine Marsh Creation Project. Monitoring elements include aerial photography, emergent vegetation, and elevation surveys, as well as reference control areas and CRMS datasets.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* Substantial technical knowledge of the processes affecting sediment and water movement throughout the Calcasieu-Sabine Basin and the ecological response of the wetland system has been established through previous measurement and numerical modeling studies. Ongoing monitoring efforts are aimed at refining our knowledge of system dynamics.

Lessons Learned and Recommendations

From a local and regional systems approach, sediment dredged for maintenance of navigation channels should be used for wetland restoration, particularly in areas that have been degraded as a result of natural subsidence and erosion, as well as navigation engineering activities. Monitoring beneficial-use sites is crucial toward gaining knowledge of proper placement techniques, including the construction and management of containment dikes. Identification of funding sources to provide the incremental costs for beneficial use of dredged material above the project Federal Standard is critical for continuing and expanding the practice of using sediment removed from navigation channels for habitat restoration purposes.

Whiskey Island Back-Barrier Marsh Creation

Project Site Location

Whiskey Island is part of the Isles Dernieres barrier island chain, located approximately 18 mi SW of Cocodrie in Terrebonne Parish, Louisiana. The island is bordered by Coupe Colin tidal pass to the west, Caillou Boca to the north, Whiskey Pass to the east, and the Gulf of Mexico to the south. Prior to initial coastal restoration activities along the Isles Dernieres in 1997, the barrier island arc encompassed four distinct islands separated by passes, including East, Trinity, Whiskey, and Raccoon Islands (McBride *et al.*, 1992). Between 1997 and 2002 beach and marsh restoration projects associated with all Isles Dernieres created substantial land

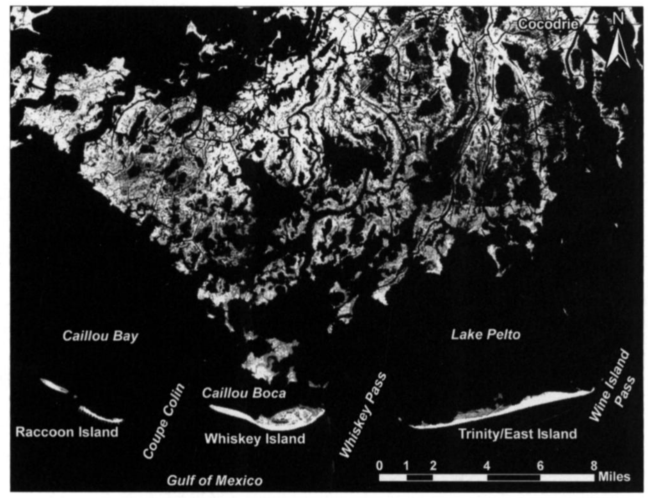

Figure 22. Location diagram for Whiskey Island, Louisiana.

areas, resulting in an enhanced barrier island system (Penland *et al.*, 2003). Furthermore, the pass between Trinity and East Islands (New Cut or Coupe Carmen) was closed in 2007, creating a continuous island between Wine Island Pass at the east end of East Island and Whiskey Pass at the west end of Trinity Island (TE-37; CWPPRA, 2007). As such, the Isles Dernieres barrier island system in 2008 was composed of three islands and three passes (Figure 22).

The Isles Dernieres barrier islands formed in response to abandonment of the Bayou Grand Caillou subdelta, the third delta of the Lafourche delta complex, approximately 500 years ago (Penland, Suter, and McBride, 1987; Figure 23). When the Bayou Grand Caillou subdelta was abandoned (no longer receiving sediment from the river), the Caillou Headland was reworked by erosive shoreface processes and longshore sediment transport. Over time, the Caillou Headland fragmented as a result of subsidence and inlet formation, generating the Isle Dernieres barrier island arc (Monitoring Plan, 2007; Penland *et al.*, 1992; Penland, Suter, and McBride, 1987). In the 1800s, Isle Derniere (meaning "Last Island" in Cajun French) was used to describe a single, large island fronting the Caillou Headland, separated from inland marshes by Lake Pelto (McBride *et al.*, 1992). Although coastal restoration in recent years has fortified the Isles Dernieres, the island arc remains composed of multiple islands and tidal inlets that formed because of fragmentation of the system once river sediment distributed through the Bayou Grand Caillou subdelta ceased to exist.

Over time the Isles Dernieres barrier island chain has evolved from a wave-dominated regime (when there was one continuous island) to a mixed-energy regime. Evidence of this is the formation of multiple tidal inlets and corresponding ebb-tidal deltas, indicating an increase in tidal influence on island morphology (Britsch, 1986; McBride and Byrnes, 1997; McBride *et al.*, 1992; Penland *et al.*, 2003). Longshore transport on Whiskey Island is localized by Whiskey Pass to the east and Coupe Colin to the west, both of which are wide,

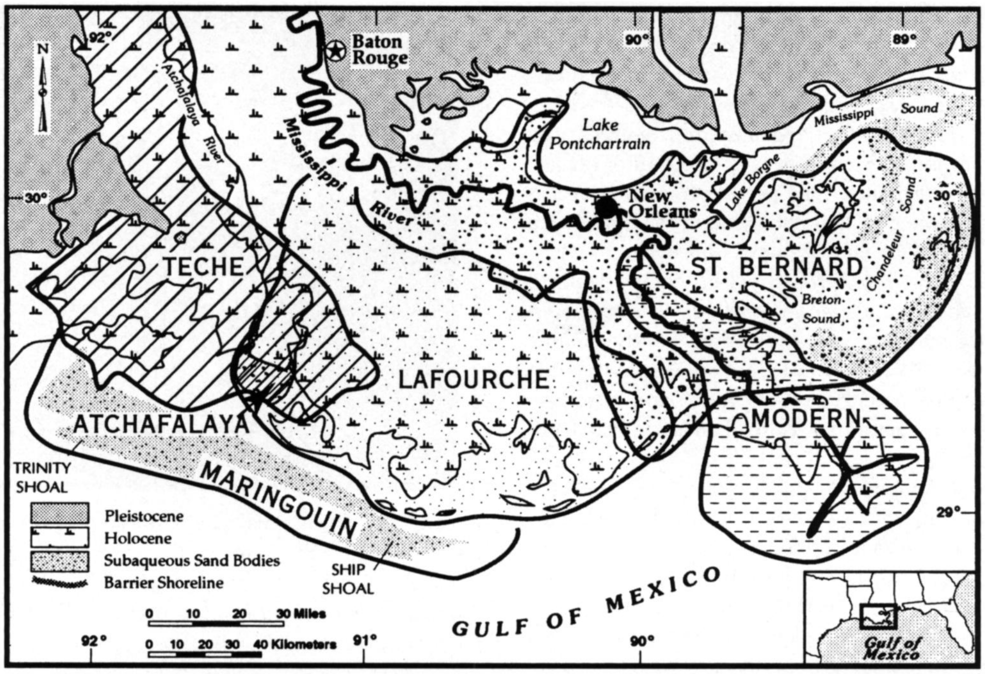

Figure 23. Approximate location of six Mississippi River delta complexes formed over the past 7000 years (from Penland, Suter, and McBride, 1987).

wave-dominated tidal passes that act as sediment sinks for littoral transport. Net longshore transport on the island is to the west, directing sand eroded from Whiskey Island to its western spit and Coupe Colin (McBride *et al.*, 1992; Monitoring Plan, 2007). Sediment transport along the eastern end of the island is approximately 6500 cy/yr, while transport toward the center and western end is estimated at about 104,600 cy/yr (Green, 2007).

The Barrier Island Comprehensive Monitoring program (BICM) was established for the Louisiana coastal shoreline to provide long-term, consistently collected data for all Louisiana barrier islands, not just those with constructed projects. The program is expected to regularly monitor coastal change in response to natural processes and engineering activities (Monitoring Plan, 2007). Shoreline change rates reported by the BICM for Whiskey Island are −52.1 ft per year from 1855 to 2005, −57.1 ft per year from 1904 to 2005, −62.2 ft per year from 1996 to 2005, and −181.4 ft per year from 2004 to 2005 (Martinez *et al.*, 2006). The Isles Dernieres barrier island chain is considered one of the most rapidly deteriorating barrier shorelines in the United States (Bolinger, Izzo, and Schmeltz, 2007). On Whiskey Island, subsidence (more than 0.4 in per year) and shoreline recession have led to a sediment deficit in the area, warranting the need for island restoration (Monitoring Plan, 2007).

Project Description

In 1998 the Whiskey Island Restoration (TE-27) project was initiated by the Louisiana Department of Natural Resources (LDNR)/Coastal Restoration Division and the Environmental Protection Agency (EPA) (Figure 24; Monitoring Plan, 2007). The restoration project was authorized in 1993 by the CWPPRA and on Priority Project List 3 of the Louisiana Coastal Wetlands Conservation and Restoration Task Force (CWPPRA, 2002b). It was part of a large-scale effort to restore the Isles Dernieres primarily through the placement of dredged sediment to maintain the protective barrier between the Gulf of Mexico and the lower Terrebonne Basin estuary system (Khalil and Lee, 2006). The Whiskey Island Restoration project included the creation of back-barrier marsh, closure of the Coupe Nouvelle breach, vegetation planting, and construction of sand fencing (Green, 2007). Approximately 355 acres of supratidal (beach, dune, barrier flat) and intertidal (beach, marsh) habitats were created using approximately 2.9 million cy of sediment dredged from Whiskey Pass (Khalil and Lee, 2006). Vegetation was planted immediately after construction in the summer of 1998 to stabilize fill sediment and again in the summer of 1999 (CWPPRA, 2002b). However, sand fencing was not erected until 1.5 years after construction. This resulted in significant loss of placed sediment due to aeolian transport and wave overwash along the fill areas of Whiskey Island (Khalil and Lee, 2006). The project was successful in increasing the sediment volume and area of Whiskey Island, but subsequent storms and other geomorphic processes have led to shoreline erosion, island narrowing, and reductions in sediment volume (Monitoring Plan, 2007).

The Whiskey West Flank Restoration Project (TE-47) is currently being evaluated as part of the CWPPRA program. It was approved for Phase I (engineering and design) funding in 2002 as part of Priority Project List 11 (CWPPRA, 2002a). However, it was not recommended for Phase II (construction)

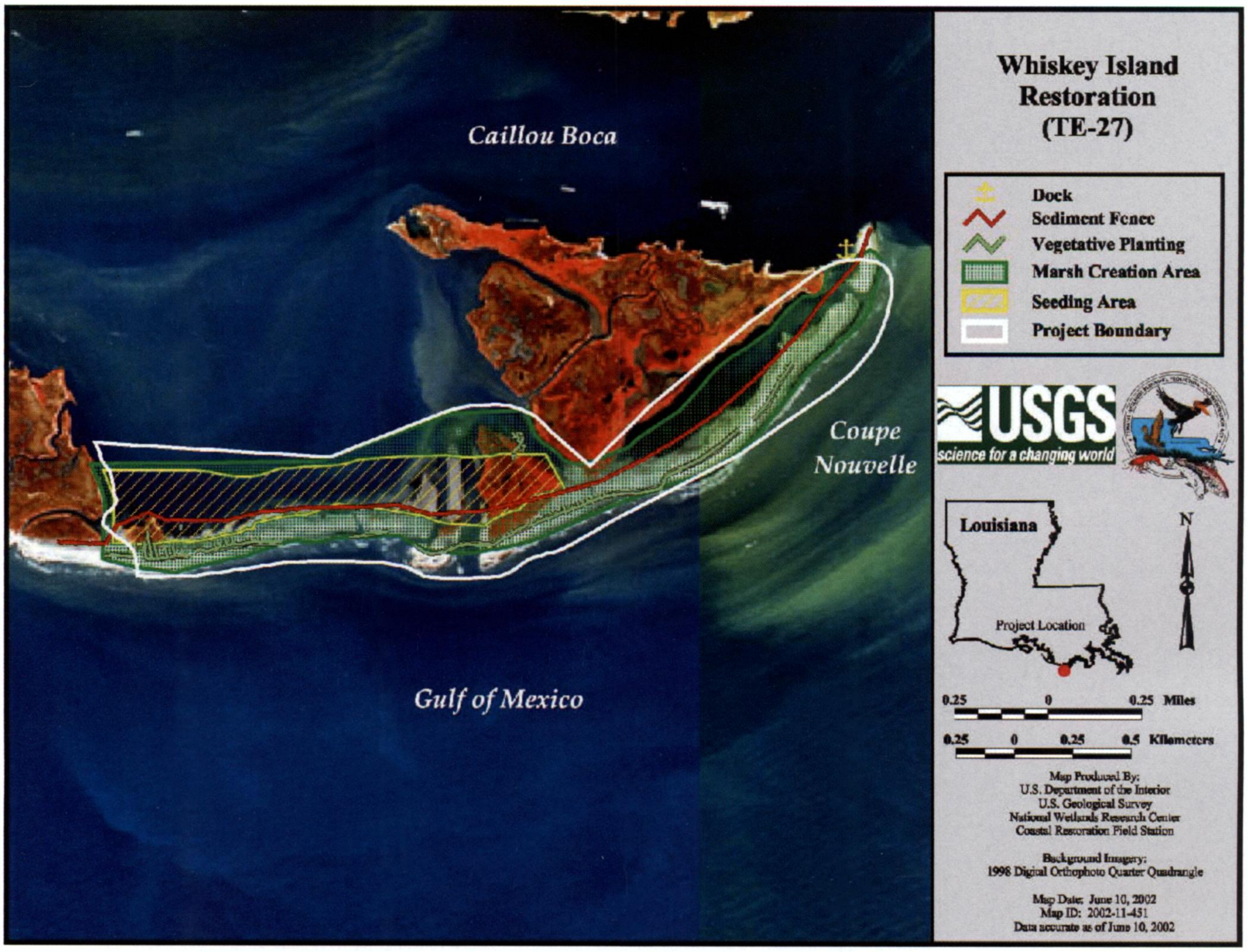

Figure 24. Whiskey Island Restoration Project (TE-27) (from CWPPRA, 2002b).

funding when engineering and design were completed in 2006. The project goals are to create a back-barrier marsh platform and to rebuild dunes on the west flank of Whiskey Island using sand dredged from Ship Shoal, an offshore shoal located approximately 8 to 10 mi south of Whiskey Island (Green, 2007). Ship shoal is a submerged relict deltaic headland, deposited during earlier stages in the evolution of the Mississippi Delta. Its composition is greater than 90% quartz sand (USACE/CPRA, 2010). The proposed borrow site on Ship Shoal is located within Block 88, approximately 10.1 mi S-SW of Whiskey Island (Bolinger, Izzo, and Schmeltz, 2007). If constructed, TE-47 would create 387 acres of dune, supratidal, intertidal, and subtidal habitats on the western spit portion of the island (CWPPRA, 2002a).

In 2004 the CWPPRA Task Force approved Phase I funding for Engineering and Design of the Whiskey Island Back-Barrier Marsh Creation Project (TE-50; Figure 25). Under CWPPRA the project cost was shared between the sponsoring federal agency (EPA) and the State of Louisiana, with the federal government providing 85% of the cost and the LDNR providing 15%. This project was designed to continue the effort to create additional back-barrier marsh habitat north of the TE-27 project completed in 2000 (EPA, 2007). The project intent was to assist the natural landward migration of the island as it washes over onto itself, thus allowing the island to respond to sea-level rise and storms. The only hindrance is the Caillou Boca channel north of the project area, which limits the northern extent of the project and hampers natural island rollover during storms and sea-level rise (Green, 2007).

Project TE-50 consisted of marsh creation on the bay side and dune creation on the Gulf side of the island. Primary earthen containment dikes were placed along 5000 ft of the northern border of the marsh creation area; secondary earthen containment dikes were placed along 12,000 ft of the eastern, western, and southern boundaries. They were constructed using approximately 167,000 cy of sediment dredged approximately 25 ft from the toe of the earthen structures in the marsh creation area (Monitoring Plan, 2007). Dredging proceeded for marsh creation in a borrow area (subarea 2A) approximately 20,000 ft SE of Whiskey

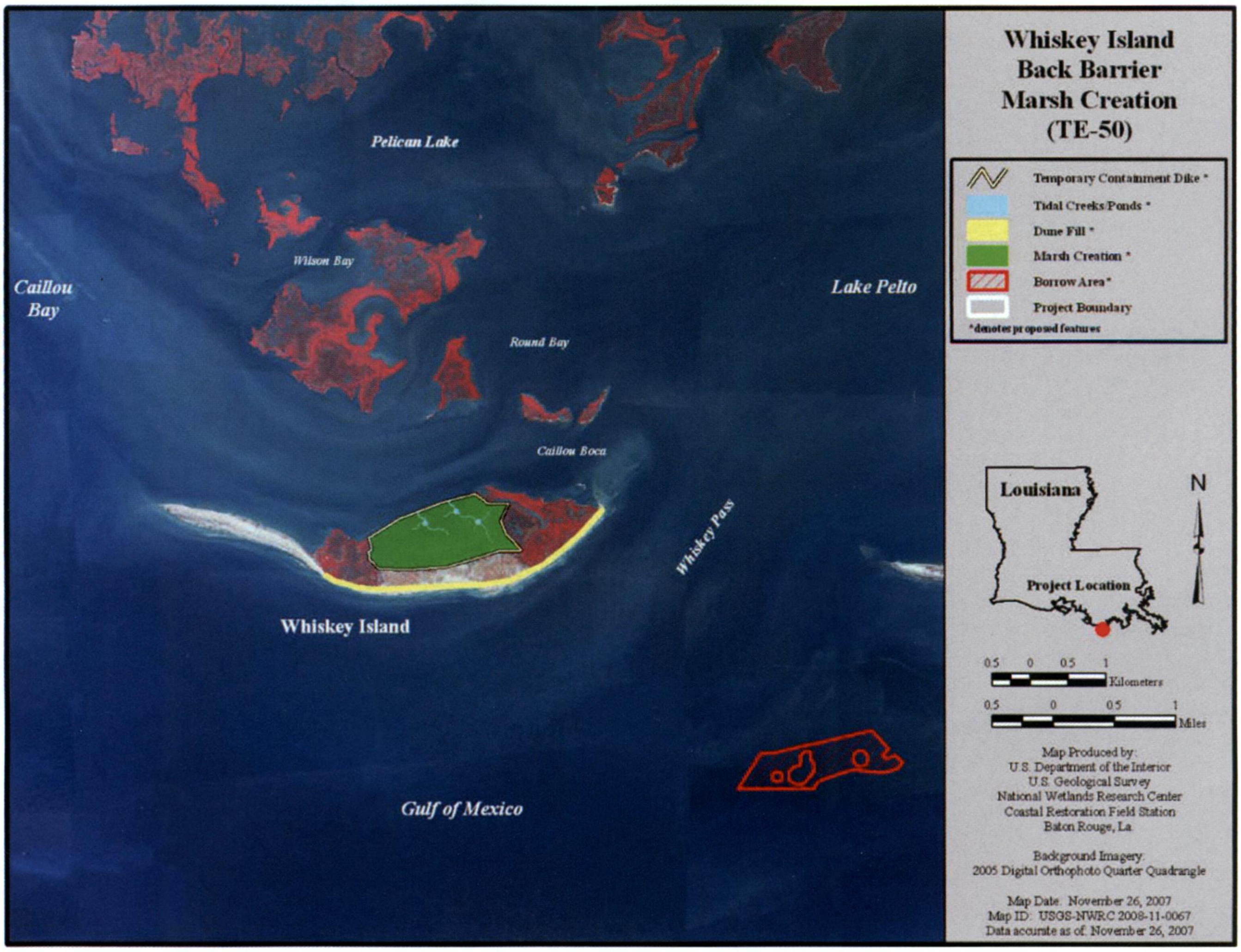

Figure 25. Whiskey Island Back Barrier Marsh Creation Project (TE-50) (from CWPPRA, 2010a).

Island. The site was chosen based on sediment availability and lower cost associated with extracting sediment from the borrow area closer to the project site. Material used to construct the back-barrier marshes came from the subsurface portion of the borrow area that consisted of clays, silts, and mixed sediments. These are deltaic sediments that overlie sand deposits. Below these mixed sediments, an estimated 2.76 million cy of sand were removed from the 230 acre borrow area. After sediment placement and consolidation, plantings were completed for stabilizing newly deposited sediment and for increasing emergent marsh vegetation (Monitoring Plan, 2007). Marsh platform elevation was designed to provide optimum habitat. The eastern portion of created marsh contains pre-excavated tidal features, while the western portion does not. The eastern marsh established a reference area to provide information as to whether construction of tidal features is necessary to achieve tidal exchange within back-barrier marshes (Green, 2007).

Dunes on the Gulf side of Whiskey Island were restored for 13,000 ft using approximately 225,000 cy of sand exposed in the borrow area after overburden mixed sediment was removed for back-barrier marsh creation (Monitoring Plan, 2007). Restored dunes are intended to provide increased protection against potential overwash and breaching. Because of natural processes, some of this sand is expected to be transported landward and deposited on the bayside of the island. Because of increased island width created by the restoration project, wash-over sand is expected to remain in the barrier island system. Sand fencing and vegetative plantings were implemented after dune creation to minimize loss of sediment. These features improve the stability of the island by slowing wind velocities, trapping sediment that could be lost to aeolian processes, and aiding in dune formation and stability (Green, 2007).

Monitoring goals established in the *Project No. TE-50 Whiskey Island Back-Barrier Marsh Creation Monitoring Plan* include the following: (1) determine the area, average width, and length of Whiskey Island and the project area over time; (2) determine the effectiveness of project features in reducing the rate of erosion as compared to historical rates of erosion; (3) determine the evolution of tidal channel development both natural and manmade; (4) determine elevation, volume, and habitat classes in the project area; and (5) determine sediment characteristics and their change over time. Monitoring strategies to provide information necessary to evaluate these specific goals include microtopography, topography, bathymetry, habitat classification, and sediment properties/geotechnical. The 20-year monitoring plan includes comprehensive reports in 2012, 2014, 2017, and 2022 describing the status and effectiveness of the project (Monitoring Plan, 2007).

Project Outcomes

Initial construction (dredge and fill) for the back-barrier marsh project began in February 2009 and was completed in October 2009, resulting in an increase in island width to help retain sand volume and elevation. Approximately 316 acres of back-barrier intertidal marsh habitat, 5800 linear ft of tidal creeks, and three 1-acre ponds were created by semiconfined disposal of dredged material. In addition, approximately 13,000 linear ft of protective sand dune were constructed along the Gulf side of the island by placement of dredged material (CWPPRA, 2010a). Vegetative plantings began in Spring 2010, but because of access issues related to the Deepwater Horizon oil spill, completion of the project was not until September 2010. Current project costs are $30,138,970, including 20 years of monitoring and O&M (CWPPRA, 2010b).

Whiskey Island has regained land critical for storm surge protection for Terrebonne Parish while creating habitat for numerous plants and animals. Oil and gas infrastructure in the region also gains added protection (USACE/CPRA, 2010).

In 2010 the USACE New Orleans District proposed a large scale restoration of the Terrebonne Basin Barrier Shoreline, which isolates the Terrebonne Basin estuaries from the Gulf of Mexico. As a subset of the National Ecosystem Restoration (NER) Plan, Whiskey Island Plan C was chosen to be constructed first. This was designed to complement Whiskey Island Back-Barrier Marsh Creation (TE-50) project by restoring the beach and dune gulfward of the completed project (Figure 26). The proposed project would involve adding 469 acres of habitat to the existing island footprint, increasing the island to 1272 acres. Ship Shoal and Whiskey 3 borrow areas would be sources of restoration sediment (USACE/CPRA, 2010).

RSM Principles Applied

Application of RSM principles throughout the Whiskey Island Back-Barrier Marsh Creation project is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* The borrow area chosen for Whiskey Island Back-Barrier Marsh Creation (TE-50) project was optimized. The overburden material was used for marsh creation, and the underlying sand was used for dune restoration. The borrow area had just the amount of material needed to complete the project, minimizing waste and leaving other borrow subareas untouched for future restoration projects. By immediately using the underlying sand deposit, contamination of sand from removal of overburden was prevented.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* Whiskey Island was cut off from its original source of sediment when the Mississippi River changed course, and since then it has been erosional. Westward littoral transport supplied sediment to downdrift beaches until Whiskey Pass enlarged enough to inhibit this transport process. Now, Whiskey Island will need to be continually nourished if it is to remain viable as an island.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* Interaction and cooperation among Federal, State, and local agencies led to the successful completion of about 315 acres of Whiskey Island back-barrier marsh.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* By restoring back-barrier marsh at Whiskey Island, the width of the island increased, providing a marsh platform with adequate elevation to retain sediment when island rollover ocurrs. This promotes sediment retention within the barrier island system rather than allowing washover deposits to form in (or be lost to) subaqueous environments such as Caillou Boca Channel to the north of the island.

(5) *Integrate a systems approach to the management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Not applicable for this project.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale.* A detailed monitoring report and plan was established for the Whiskey Island Back-Barrier Marsh Creation (TE-50) project. Information gathered from monitoring tidal-feature formation on the back-barrier marsh can be applied to future marsh creation projects in similar back-barrier settings. The first monitoring report is expected to be completed in 2012.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* When using shoal deposits in Whiskey Pass as a restoration borrow site, sand that would have been transported by littoral processes to Whiskey Island from Trinity and East Islands prior to inlet formation is being dredged and placed in its natural downdrift location. Inlet formation and expansion that created a natural gap in the littoral transport system was bridged using sand extracted from a borrow site sourced by west-directed sand transport for island restoration.

Lessons Learned and Recommendations

According to Britsch (1986), McBride *et al.* (1992), and McBride and Byrnes (1997), the Isles Dernieres are in a mature stage of delta barrier island development. Since the

Figure 26. Proposed Terrebonne Basin Barrier Shoreline Restoration, Whiskey Plan C (from USACE/CPRA, 2010).

natural tendency of the system is to eventually succumb to subsidence and erosion, this project will not be enough to sustain Whiskey Island indefinitely. As such, future restoration efforts will be required to maintain the island and its many benefits relative to coastal habitat and watershed/mainland storm protection.

When RSM principles are applied, borrow areas with mixed-sediment sources can be used effectively to maximize beneficial uses of all available sediment to minimize contamination/waste of valuable sediment resources.

Gulf Intracoastal Waterway–Laguna Madre Avian Habitat

Project Site Location

Laguna Madre is a long, narrow, hypersaline lagoon extending from Corpus Christi Bay to Port Isabel, Texas, near the U.S.-Mexican border (Figure 27; USACE, 2003). The lagoon formed during the most recent rise in sea level that inundated the coastal plain bordering the Gulf of Mexico. During sea-level inundation the lagoon flooded various geological provinces, including a former barrier island system, an aeolian plain, and abandoned portions of the Rio Grande delta (Morton, White, and Nava, 1998). Laguna Madre is separated from the Gulf of Mexico by Padre Island. The lagoon is naturally divided into two basins, Upper Laguna Madre (ULM) and Lower Laguna Madre (LLM), by Saltillo Flats, an extensive area of sporadically inundated tidal flats. The Gulf Intracoastal Waterway (GIWW), a chain of navigable channels extending from Florida to near the Mexican border, runs through Laguna Madre, permanently connecting the two basins by a section dredged through Saltillo Flats known as the Land Cut (USACE, 2003). The Laguna Madre section of the GIWW is 117 mi long from the JFK Causeway to the old Queen Isabella Causeway.

Laguna Madre is one of five hypersaline coastal ecosystems in the world (Onuf, 2007). Extensive seagrass, or submerged aquatic vegetation (SAV), communities are present in Laguna Madre and serve as an important component of the ecosystem (USACE, 2003). At present, seagrass meadows cover 65% of the bottom of the lagoon and account for more than 75% of seagrass cover along the Texas coast (Onuf, 2007). Seagrass ecosystems sustain considerable amounts of estuarine and near-shore marine production (Brown and Kraus, 1997). They provide critical habitat for fish and waterfowl, including a large percentage of the world population of the redhead duck, which winters in the lagoon and feeds on the rhizomes of shoal grass (Onuf, 2007).

The hypersaline conditions of Laguna Madre are a result of the limited water exchange with the Gulf of Mexico, negligible fresh water inflow, and high evaporation rate. There are three permanent openings allowing exchange of

Figure 27. Location diagram for Laguna Madre, Texas.

water with the Gulf: Brazos Santiago, Mansfield Pass, and Aransas Pass. Because of limited connections between Laguna Madre and the Gulf of Mexico, and water depths that average about 3 ft, the lagoon is classified as microtidal with a mean tidal range varying from 1 ft in the vicinity of passes to a few centimeters in the interior. During strong winds, wind-driven circulation can dominate over that produced by tides. For most of the year the region experiences strong SE winds, but strong north winds associated with cold fronts are prevalent during the winter (Brown and Kraus, 1997).

Laguna Madre acts as a sediment trap that receives sediment from aeolian, fluvial, tidal, and overwash processes; however, the total amount of new sediment introduced by these processes is substantially less than the volume dredged from the GIWW. This leads to the conclusion that shoaling in the Laguna Madre section of the GIWW is primarily caused by internal reworking of sediment within the lagoon that results from lagoon margin erosion and resuspension of lagoon floor sediments by waves and currents (Morton, White, and Nava, 1998).

Project Description

On July 23, 1942, Congress authorized enlargement of the GIWW to include the Laguna Madre section with dimensions of 12 ft deep and 125 ft wide. Construction commenced in 1945 and was completed on June 18, 1949. Channel dimensions remain the same today, but allowable overdraft and advanced maintenance result in a 16-ft depth. Every 23 to 60 months the main channel requires maintenance dredging in certain reaches to remove approximately 200,000 to 3 million cy of sediment. Dredging is performed by cutterhead suction dredges, and dredged material is placed by hydraulic pipeline on both upland and open-bay disposal areas. The original project identified 63 PAs, of which 61 are intermittently used, consisting primarily of unconfined open-bay placement with upland placement where the channel crosses the Land Cut and a few other locations for maintenance dredging of the Laguna Madre section of the GIWW (USACE, 2003).

Project Outcomes

Results from the 1975 Environmental Impact Statement (EIS) for maintenance dredging raised concerns over the environmental effects of open-water placement practices (USACE, 2003). Even though construction of the waterway was beneficial for improving circulation, reducing hypersaline conditions, and allowing seagrass to colonize areas that were formerly uninhabitable, maintenance operations negatively affected seagrass survival locally in Laguna Madre (Figure 28). Turbidity plumes near placement sites have contributed to localized burying of seagrass and the blocking of sunlight needed to carry out photosynthesis (Crear, 2004). The fine, unconsolidated mounds of dredged material are much more prone to resuspension by waves and dispersion by currents (Onuf, 2007).

Furthermore, reduction in salinity levels resulting from the connection of the two basins through the GIWW Land Cut altered species composition in Laguna Madre. A decrease in salinity levels to around 50 parts per thousand (ppt) caused a reduction of shoal grass, the only species that can tolerate salinities greater than 60 ppt, and an increase in species that thrive in a habitat with more moderate salinity (Figure 28; Onuf, 2007).

Although the USACE was in the process of conducting a Section 216 study to supplement the existing EIS and review the project for modification because of changes in environmental or economic conditions, continuing concerns over placement of maintenance-dredged material led to a 1994 lawsuit involving the National Audubon Society and the USACE. Final judgment on this case occurred while the USACE was conducting the Section 216 review of current maintenance and operation of the Laguna Madre section of the GIWW. Plaintiffs' claims were denied, and the case was dismissed on October 13, 1994, with the Court's understanding that a SEIS and long-term DMMP would be prepared.

To aid in the development of the SEIS, the USACE and the Texas Department of Transportation (TxDOT), the project's local sponsor, developed an Interagency Coordination Team (ICT) to identify environmental concerns associated with the GIWW in Laguna Madre and to develop scopes of work to address these concerns (Onuf, 2007). The ICT consisted of representatives from State and Federal resource agencies,

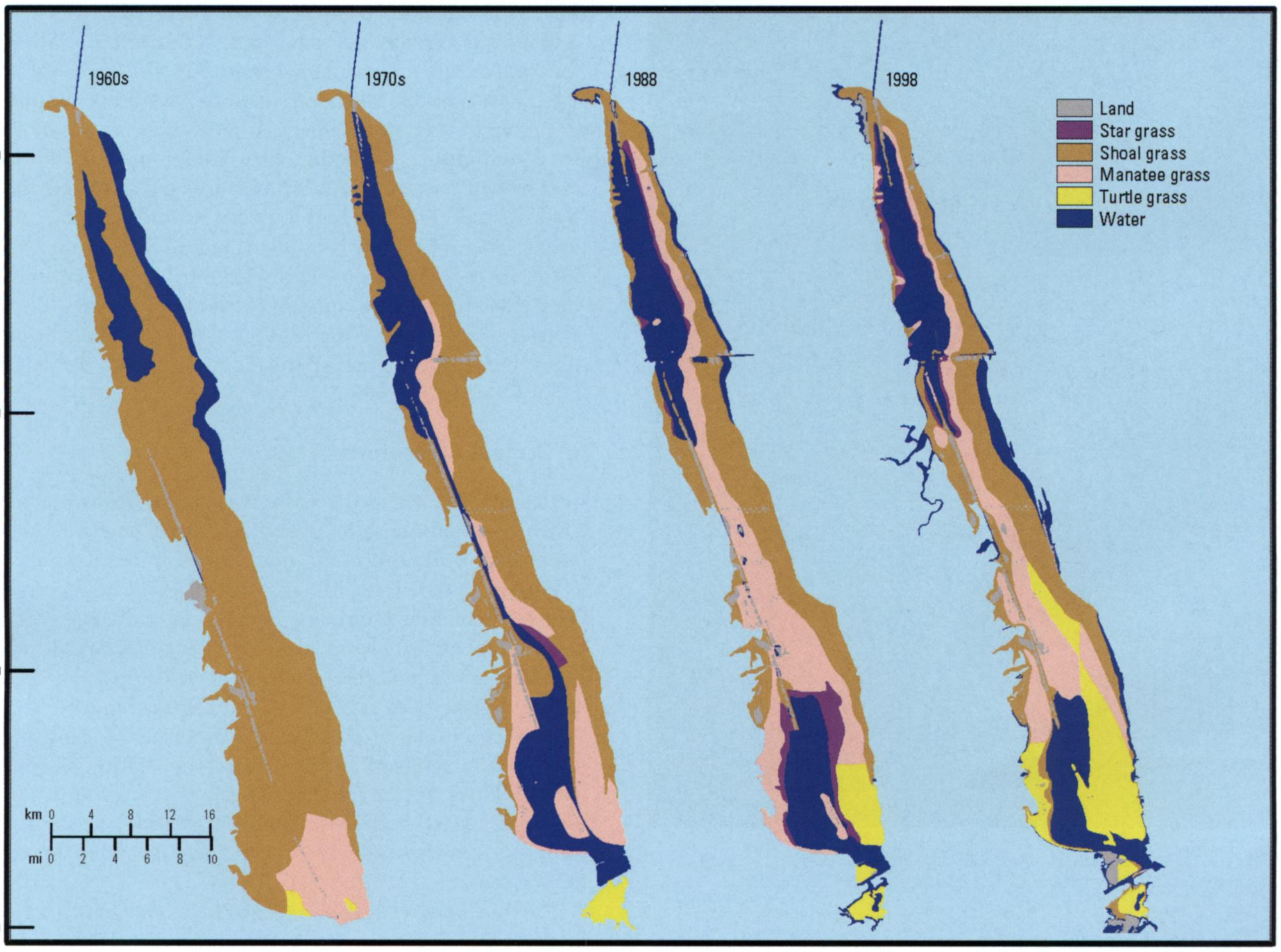

Figure 28. Distribution of seagrass in Lower Laguna Madre from the 1960s to 1998 (from Onuf, 2007).

including TxDOT, Texas General Land Office (TGLO), Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, Texas Water Development Board, National Marine Fisheries Service, U.S. EPA, U.S. Fish and Wildlife Service, and USACE, as well as two advisory members: Padre Island National Seashore (PINS) and Coastal Bend Bays and Estuaries Program. Environmental studies performed by the ICT included water and sediment quality, benthic macrofauna analysis, open-water placement, models of circulation and sediment transport, seagrass distribution and productivity, economic impacts, depth measurement and bottom classification, and effects to piping plovers (USACE, 2003).

The existing maintenance plan for the Laguna Madre section of the GIWW was modified to reduce impacts to natural resources of the lagoon. In 2003 the Corps, with the help of the ICT, released the Final Environmental Impact Statement (FEIS), which identified four general types of dredging and placement alternatives:(1) open ocean/offshore placement, (2) upland placement, (3) beneficial use, and (4) open-bay placement. Factors evaluated while analyzing these options included effects on water quality, sediment quality, seagrass and wetland aquatic habitats, finfish and shellfish resources, wildlife resources, threatened and endangered species, cultural and socioeconomic resources, and cumulative impacts (USACE, 2003).

The FEIS included the DMMP. The plan was developed by considering alternative maintenance dredging and placement methods to identify the least environmentally damaging alternatives that were within the engineering capabilities of the Corps and were economically feasible. Management of PAs would be primarily to reduce impacts to nearby seagrass habitat, but some PAs would be managed for bird use, vegetation control, or public recreation. The ICT recommended the final DMMP for Laguna Madre be divided into six reaches (Figure 29; USACE, 2003).

Ultimately, the ICT decided to develop a separate plan for each individual PA located within each reach. Factors considered while designing the management plans for each PA included frequency of use, quantity of dredged material placed in the PA per dredging cycle, size of the PA, grain size, and nearby seagrass coverage. Under the recommended plan it was estimated that 1307 fewer acres of seagrass and 49.3 fewer acres of tidal flats would be impacted compared to the previous method of maintaining the Laguna Madre section of

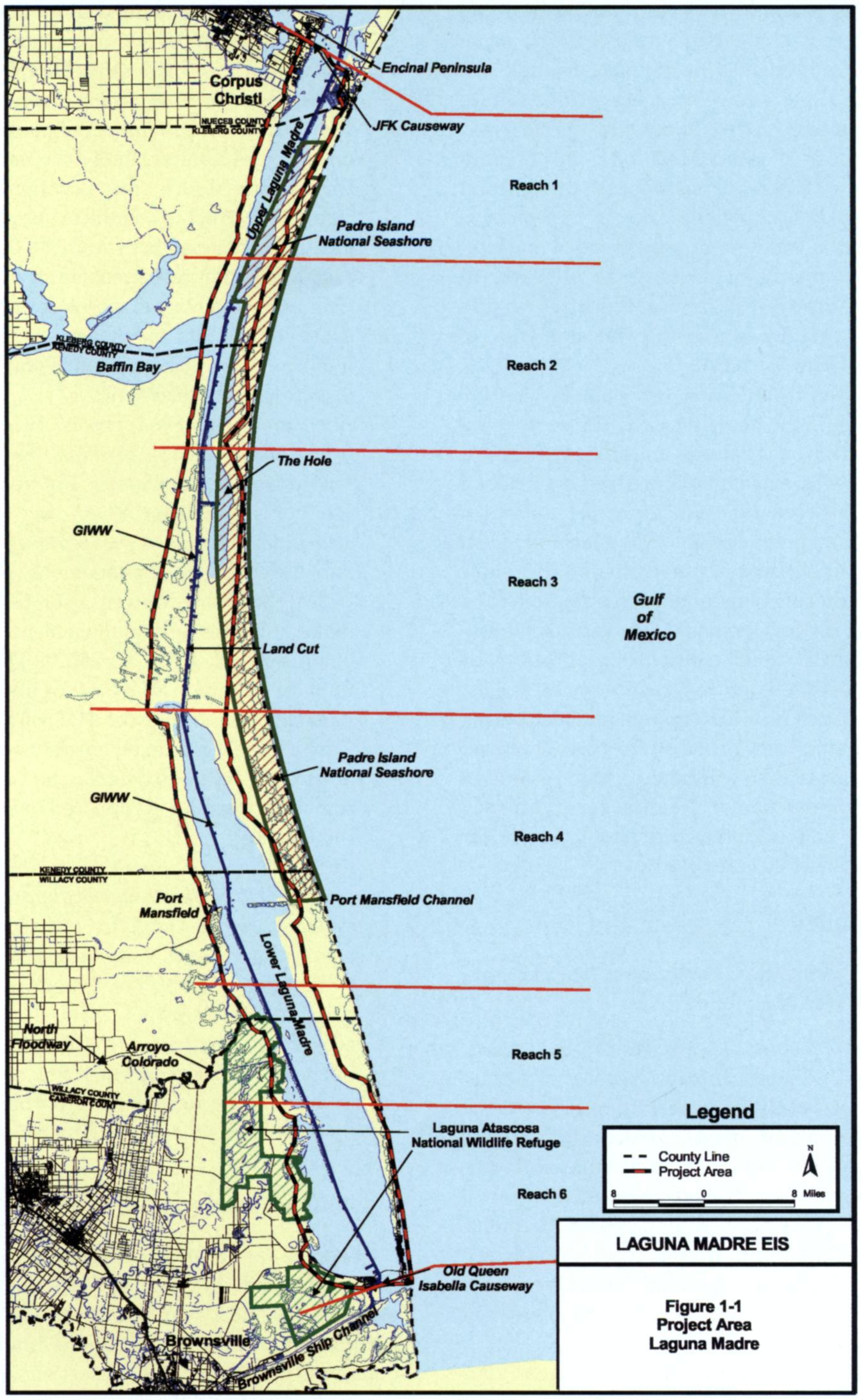

Figure 29. Laguna Madre Reaches 1 through 6 developed by the Interagency Coordination Team (from USACE, 2003).

the GIWW. The recommended plan would reduce the amount of unconfined open-bay placement, therefore reducing impacts on the natural resources of Laguna Madre. This would be completed through greater retention of sediments on islands by using training levees or complete confinement within existing PAs where feasible, controlling vegetation and increasing the size of islands for enhancing colonial waterbird use (beneficial use), and relocation or extension of some PAs to nearby deep, unvegetated areas (Crear, 2004).

Turbidity modeling studies were performed to determine the effects of total suspended solids on seagrass in the lagoon. Turbidity levels high enough to prevent or reduce photosynthesis, and therefore seagrass survival, were found to be short term (about 3 months or less) and in an area within 1 km of the dredged-material placement discharge point. To reduce the impact of turbidity associated with maintenance dredging and placement, it was recommended to fully confine some PAs, use training levees to retain sediment on the islands, use unvegetated deep-water sites, and restrict operations to late fall to early spring when seagrass is dormant (Crear, 2004).

The plan recommended in the DMMP for the Laguna Madre section of the GIWW included less unconfined placement than previously completed. This is expected to lead to a reduction in the amount of resuspended maintenance material, an accompanying decrease in shoaling in the affected reaches of the GIWW, and a reduction in the frequency of dredging, thereby increasing the efficiency of maintenance dredging (USACE, 2003).

A monitoring plan for the DMMP was developed by the ICT and USACE to determine if the goals for each PA were being achieved. The plan focused on localized impacts at each PA, including results from the beneficial use of dredged material on some islands to enhance bird habitat, reducing direct impacts to seagrasses from burying and indirect impacts to seagrasses from turbidity plumes, and the releasing of nutrients into the water column. The original monitoring plan included parameters to be monitored, locations and methodology to use, and implementation responsibilities (USACE, 2003). Monitoring efforts to be conducted as part of the Texas GIWW Seagrass Mapping Project are expected to provide information on mapping and monitoring subaqueous seagrass communities. Based on the current project statement of work, data acquisition will focus on high resolution aerial photography and production of a digital terrain model, digital elevation model, and orthorectified photo mosaic for assessing seagrass conditions (Calnan, 2011).

RSM Principles Applied

Application of RSM principles throughout the Laguna Madre section of the GIWW is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* The USACE and State partners generally recognized the value of dredged sediment as a resource for habitat restoration and creation. However, environmental concerns regarding the viability of seagrass beds in response to dredged material placement and increased turbidity throughout the project area direct interests toward upland habitat creation for colonial waterbird use. Confined dredged material PAs are the most beneficial use in the Laguna Madre area.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* The DMMP included beneficial uses of dredged material, although there were few opportunities for placement within the Laguna Madre area. Beneficial use included the creation of colonial waterbird habitat and enhancement of islands associated with PAs within the PINS.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* The USACE formed the ICT to aid in the development and application of RSM practices through the DMMP. A primary goal of the ICT was to ensure effective team communication and coordination among State and Federal agencies.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* Emphasis has been placed on the impact of dredged material placement on seagrass habitat, likely the most important habitat in the Laguna Madre area. Location of PAs and constructed colonial waterbird habitat depends on proximity of localized seagrass beds and the dominant local processes responsible for resuspension of placed dredged material. Upland or offshore disposal of dredged material becomes a primary option for placement when localized seagrass habitat can be so significantly impacted by turbidity from dredging and placement.

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Not applicable for this project.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale.* The ICT has agreed that management plans contained in the DMMP will be reviewed prior to each dredging event to make sure the best management practice for each PA is being applied (USACE, 2003). The USACE will monitor impacts of the DMMP and make revisions based on recommendations of the ICT, if necessary (Crear, 2004). This adaptive management-decision process is expected to ensure the best outcome for the Laguna Madre ecosystem. A monitoring plan is supposed to accompany the DMMP in the future.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* Significant technical information is available regarding the dynamics of water/sediment and benthic communities throughout the Laguna Madre ecosystem. Furthermore, the ICT was established for the purpose of assisting with the development of scientific investigations to address environmental concerns raised by resource agencies and environmental groups.

Lessons Learned and Recommendations

Seagrass is a vital component of the Laguna Madre ecosystem and is vulnerable to changes in water quality, such as turbidity and salinity. Proper management of maintenance dredging operations, such as the use of confined open-bay placement and observing dredging windows that correspond with the seagrass dormant period, can reduce impacts to the surrounding environment. Reduced open-bay placement also leaves more sediment for beneficial use where opportunities arise.

It is important to apply adaptive management techniques and monitor the environmental effects of maintenance dredging and placement in order to determine if a redesign of management plans is warranted. Ideally, FEIS and DMMP documents provide for better management of sediment dredged from Laguna Madre for the purpose of maintaining the GIWW.

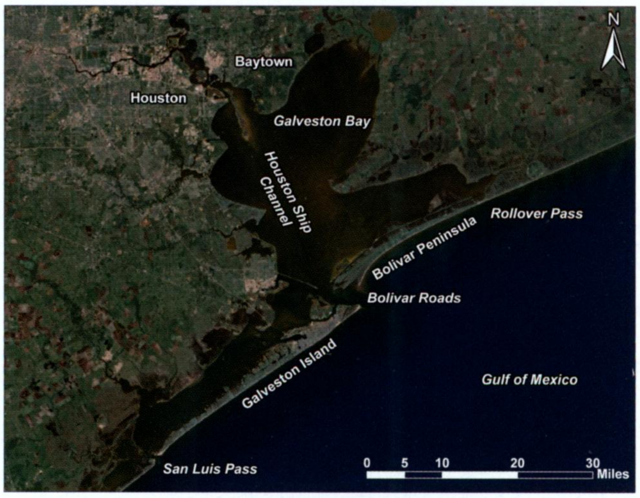

Figure 30. Location diagram for Houston Ship Channel, Texas.

Houston Ship Channel: Dredged Material Management Plan

Project Site Location

Galveston Bay is a relatively shallow body of water approximately 600 square mi in area located along the NE Texas coastline (Figure 30; USACE, 2010). The bay is a bar-built estuary that formed in a drowned river delta (Sage and Gallaway, 2002). Running for approximately 53 mi in a NW direction from the Gulf of Mexico, through Galveston Bay, and to the port of Houston is the federally maintained Houston Ship Channel (HSC) (USACE, 2010). The ship channel delivers surface flow from San Jacinto River and much of the drainage from the city of Houston to upper Galveston Bay (Sage and Gallaway, 2002). The HSC is part of a series of deep-water navigation channels, known collectively as the Houston-Galveston Navigation Channel (HGNC), which provides access to the deep-water ports of Houston, Texas City, Bayport, and Galveston (USACE, 2010).

Hydrologic patterns in Galveston Bay are dominated by tidal forces (USACE, 2010). There are three tidal inlets allowing for exchange between Galveston Bay and the Gulf of Mexico: (1) Bolivar Roads, which accounts for a majority of the exchange and is located between Galveston Island and Bolivar Peninsula; (2) San Luis Pass, which provides a lesser amount of tidal exchange and is located between the western end of Galveston Island and Follets Island; and (3) Rollover Pass, a man-made cut through Bolivar Peninsula that allows only minor tidal exchange (Sage and Gallaway, 2002). Tides in the region are semidiurnal with two high and two low tides each day. The typical tidal range is about 1 ft, although this can increase as a result of spring tides and storm events. Currents in the central portions of the bay are in the direction of prevailing winds and also influence circulation patterns. As fronts pass through the region during winter, prevailing winds are from the N and NW, resulting in water piled up against the bay side of the barrier islands. In the summer, winds are predominantly from the S and SE, leading to water being forced toward the mainland shoreline (USACE, 2010).

Project Description

Improvements in the region began under an appropriation in 1872 for a cut 7.5 ft deep, 70 ft wide, and 1500 ft long through a region in central Galveston Bay called Red Fish Bar (ARCE, 1915). By 1914 the HSC opened at a depth of 25 ft (USACE, 2010). Material dredged from Galveston Bay requiring open-water disposal prior to WWII was sidecast, mostly at the dredger's convenience. By the 1960s, after multiple improvements, the HSC had dimensions of 40 ft deep and 400 ft wide in order to accommodate larger ships. Since the 1960s, specific regions have been identified and permitted by the EPA and the Corps for placement of dredged material (Ward, 1993).

In 1969 the Port of Houston Authority requested further modifications of the ship channel (Betterbay, 2010). A feasibility study was completed in 1987 for improving the Houston and Galveston channels, recommending depths of 50 ft (USACE, 2010). This raised environmental concerns regarding the impacts of greater salinity intrusion, burial of bottom fauna by dredged material, and higher turbidity from open-bay disposal (Sage and Gallaway, 2002). Ultimately, a Limited Re-evaluation Report and SEIS were completed in 1995, recommending channel dimensions of 45 ft deep and 530 ft wide. These studies were completed with the formation and assistance of an ICT, which comprised local, state, and Federal agency representatives. The team oversaw studies on contaminants, benthic recovery, cumulative impacts, oyster reefs, a ship-handling simulation model, a three-dimensional hydrodynamic and salinity model, and beneficial uses of dredged material (USACE, 2010).

The BUG, formed in 1990 as a subcommittee of the ICT, was charged with identifying environmentally and economically responsible ways to use dredged material from the HGNC expansion. The BUG is a partnership of eight agencies: the Port of Houston Authority (the project's local sponsor), the USACE (the project's Federal sponsor), the U.S. EPA, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the Natural Resources Conservation Service, the Texas Parks and Wildlife Department, and the TGLO. The resulting plan was one in which all new and maintenance material would be placed in designated areas in the Gulf of Mexico, used beneficially in the Gulf or Galveston Bay, or placed in confined upland areas (USACE, 2010). Over the 50-year project life, the dredged material placement plan (BUG Plan) included dredged-material placement to create over 4200 acres of wetlands, a 6-acre bird island, 172 acres of oyster reef, restoring Redfish and Goat Islands, and creating an offshore beneficial-use berm (Figure 31; Saunders, 2009).

Because of a general lack of experience with beneficial-use construction of this magnitude, the BUG designed a Demonstration Marsh in 1992 for the purpose of identifying key environmental design parameters and management requirements needed for establishment, growth, and survival of created marsh. A 220-acre demonstration marsh located in

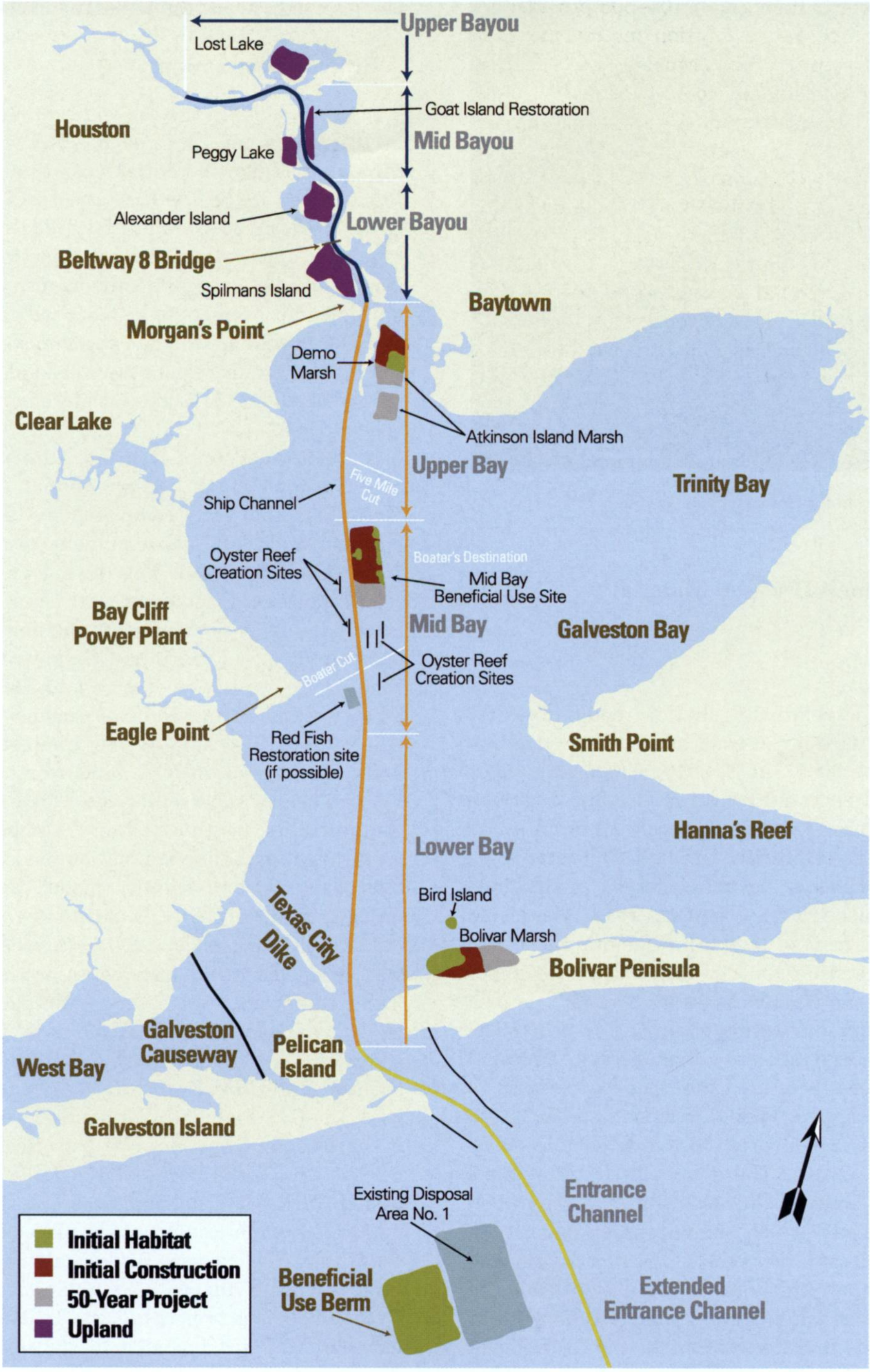

Figure 31. Houston Ship Channel 50-year plan for beneficial use of dredge material (from PHA, 2005).

upper Galveston Bay was created from maintenance dredging of the Bayport Ship Channel flare. Lessons learned were applied to the BUG Plan for the HGNC expansion (Koenig, 1997).

Furthermore, the BUG is involved in the development and application of a monitoring, management, and maintenance plan (M3 Plan) for each marsh site. This provides the project local sponsor, the Port of Houston Authority, with guidance for protecting marshes by establishing procedures for monitoring and maintenance to ensure proper development. The M3 Plan relies on continued documentation of progress associated with created marshes, including lessons learned from the demonstration marsh (PHA, 2003).

On October 12, 1996, the Water Resources Development Act of 1996 Sec. 101 (30) of Public Law 104–303 provided for navigation and environmental restoration improvements to the HGNC. Navigation improvements consisted of deepening and widening the entrance channel to 47 ft deep and 800 ft wide, the HSC to 45 ft deep and 530 ft wide, and the Galveston Channel to 45 ft deep. The environmental restoration portion of the project consisted of initial construction of marsh habitat and a colonial water-bird nesting island through the beneficial use of new work dredged material and incremental development of additional marsh over the life of the project through the beneficial use of dredged maintenance material. In 1998 deepening and widening of the HGNC commenced. By 2005 the HSC and entrance channel were opened to allow vessels drawing 45 ft of water (USACE, 2008). The entrance channel was improved for 14.4 mi and the HSC for 26 mi across Galveston Bay and 13 mi in the Bayou Reach (USACE, 2007).

Project Outcomes

Based on the large amount of dredged material used for habitat restoration and creation, the project was a success with respect to RSM principles. Bolivar Marsh, an 800-acre intertidal salt marsh, was created in the lower bay adjacent to the north side of the Bolivar Peninsula. Evia Island, a 6-acre bird sanctuary, was created 1 mi north of the Bolivar Peninsula. In the middle of Galveston Bay, Redfish Island was restored, and Mid-Bay Island, a 600-acre site consisting of both upland habitat and marsh habitat, was created. Atkinson Marsh (800 acres) was created in upper Galveston Bay. In the bayou section of the HSC, Goat Island was restored, providing upland wildlife habitat (Betterbay, 2010).

Since improvements were made to the HSC, increased shoaling rates have required earlier than planned construction of beneficial-use PAs. The problem is greatest for project reaches that use PAs 14 and 15 and the associated beneficial-use sites for placement of maintenance material in the Upper Bay (see Figure 31). To address long-term capacity shortfalls, the Galveston District (USACE) plans to revise the existing DMMP (USACE, 2010). Unanticipated shoaling from deepening the HSC from 40 to 45 ft and widening it from 400 to 530 ft has nearly doubled the annual maintenance dredging cost from $14.9 million in 2005 to $28.4 million in 2007 (CHL, 2010).

The U.S. Army Engineer Research and Development Center (ERDC), Coastal Hydraulics Laboratory (ERDC-CHL) completed an investigation in 2008 to validate the sediment transport model used for the HSC and Trinity Bay area based on a comparison of model results and field data (CHL, 2010). Vessel traffic was found to have an influence on deposition and resuspension of sediment and was included in the study. The model underpredicted the magnitude of channel shoaling based on a comparison with maintenance dredging data. Model refinement was required to properly simulate sedimentation that was more representative of the system being examined (Tate, Berger, and Ross, 2008).

The Galveston District proposed a project that involved joining PAs 14 and 15 to increase dredged material placement capacity for maintenance dredging in the Upper Bay Reach of the HSC and the Bayport Ship Channel (Figure 32). The proposed 169-acre expansion has a capacity of approximately 10 million cy. The project would provide an opportunity to use dredged material beneficially for intertidal marsh creation, as well as provide net ecological benefits to the Galveston Bay ecosystem (USACE, 2010).

The HGNC continues to be evaluated by ERDC-CHL under the Monitoring Completed Navigation Projects (MCNP) program (Rosati, Sanchez, and Tate, 2011). Study objectives are to evaluate navigation channel shoaling processes in the HGNC, develop improved methods for estimating navigation channel shoaling, and provide recommendations to reduce future shoaling. Future capacity of dredged material placement sites also will be considered. Field data collection began in June 2010 and will be used to aid in the calibration and validation of the Coastal Modeling System (CMS) (Bridges, 2010). The CMS is an integrated numerical modeling system that takes into account waves, currents, sediment transport, and morphology change. Anticipated outcomes of the study include a calibrated CMS and a reduction in O&M dredging (Bridges, 2010). Rosati, Sanchez, and Tate (2011) evaluated historical shoaling data for the HGNC to document and understand changes in shoaling with time. Specifically, they evaluated decreases in shoaling recorded between 1948 and 1995 versus increases that occurred after channel deepening and widening in 1995. Preliminary findings suggest that unexplained anomalies in dredging data may have biased shoaling trends. Knowledge gained from these projects is expected to be applied to other coastal navigation projects to more reliably predict channel shoaling.

RSM Principles Applied

Application of RSM principles throughout the Houston-Galveston Ship Channel Project is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* The sediment dredged for the Houston-Galveston Ship Channel widening project was used as an environmental resource for various marsh restoration and creation projects throughout Galveston Bay, as well as a beneficial-use berm at the entrance to the bay. This plan, designed by the BUG, used dredged sediment that previously was disposed of in the open bay to build wildlife habitat and enhance the Galveston Bay system.
(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* The deepening and widening of the HGSC was a large undertaking by the USACE, and an important part of the project was placement of new work dredged material and maintenance material. The project was seen as an opportunity to use sediment to enhance and create habitat.
(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* The ICT and BUG were developed for this purpose.
(4) *Make local project decisions in the context of the sediment system and consider regional implications.* All decisions

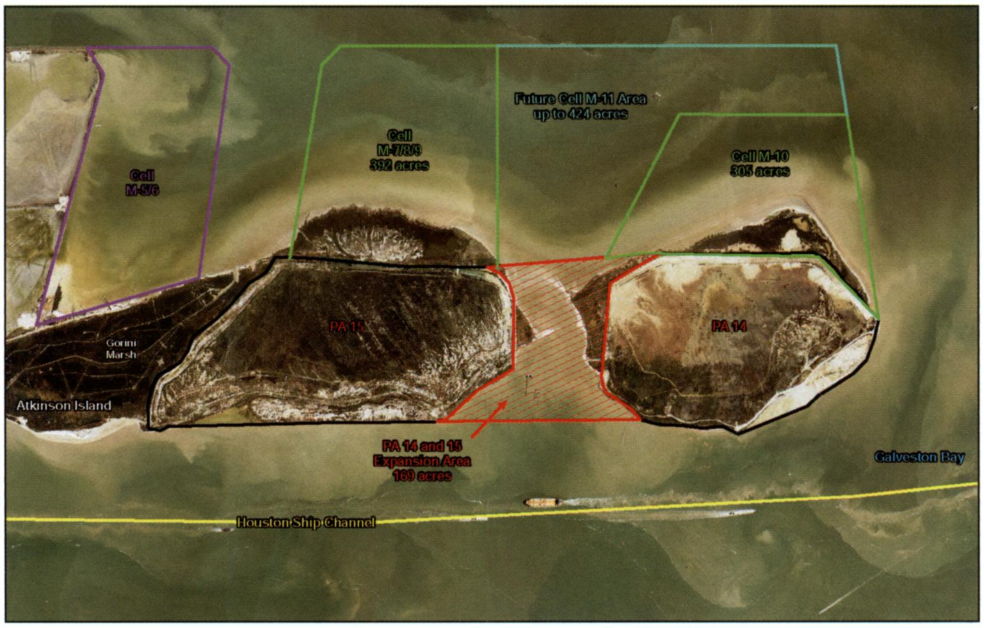

Figure 32. Proposed plan for expansion of Placement Areas 14 and 15 (from USACE, 2010).

regarding beneficial use of dredged material were intended to restore existing or establish new marsh, benthic, and upland habitat. Unexpected increases in maintenance dredging after channel deepening suggests the system should have been studied further in order to understand its dynamics prior to the HGSC improvement project. It is anticipated that monitoring data and calibrated model results will provide a better understanding of sediment dynamics throughout the Galveston Bay system.

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Not applicable for this project.
(6) *Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale.* A Monitoring, Management, and Maintenance Plan was established by the BUG for each marsh site. The BUG will advise the Port of Houston Authority and the Corps as the benefiicial-use sites are managed and expanded.
(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* Greater attention should have been given to this RSM principle prior to the navigation channel improvement project. Shoaling rates should have been studied extensively so that adequate beneficial PAs for dredged material could be planned accordingly.

Lessons Learned and Recommendations

Better methods for predicting channel shoaling need to be devised and applied before a project is implemented. A clear understanding of the local and regional system and all processes involved will allow for proper project planning.

Lido Key Beach Restoration

Project Site Location

Lido Key is a 2.5-mi-long barrier island located in Sarasota County off the west coast of Florida, approximately 45 mi south of Tampa. Sarasota Bay and the Intracoastal Waterway separate the island from the mainland. New Pass, a federally dredged channel, is to the north of Lido Key, separating it from Longboat Key. Big Sarasota Pass is to the south and separates Lido Key from Siesta Key (Figure 33). The island, which ranges in width from 100 to 2500 ft, is largely developed except for North Lido Public Beach and South Lido Park. The beachfront consists of hotels, motels, and private residential and seasonal rental properties. Undeveloped upland areas and beaches provide habitat for vegetation (*e.g.,* Australian pine, palms, and sea oats) and wildlife, including small mammals, shore and wading birds, and occasionally nesting sea turtles (USACE, 2002).

The tidal range along west-central Florida is about 1.5 ft during neap tides and approximately 3 ft during spring tides. Net longshore sediment transport in the region is from north to south and is mainly the result of strong northerly winds accompanying frontal passages, which are frequent in the winter season. Net transport is estimated at 25,000 to 90,000 cy/yr to the south at New Pass, and for erosional hotspots at central and southern Lido Key net southward transport is estimated at 100,000 cy/yr (Beck and Wang, 2009). Sediment is primarily bypassed from Longboat Key to Lido Key by means of the New Pass ebb shoal. Sand is transported

Figure 33. Location diagram for Lido Key, Florida.

south by waves and deposited onto the updrift margin of the ebb shoal. A portion of the sand may infill the channel after crossing the channel linear bar (Beck and Wang, 2009), a feature characteristic of tide-dominated inlets like New Pass (Davis, Wang, and Beck, 2007). Some sediment also bypasses the inlet and reaches Lido Key after being transported around the outer edge of the ebb shoal (Beck and Wang, 2009).

Lido Key was created in the 1920s when John Ringling filled a series of mangrove islands and shallow seagrass beds known as Cerol Isles to provide residential and commercial development opportunities in the area. This altered the hydrology of the region, focusing the tidal prism at New Pass and Big Sarasota Pass (Davis, Wang, and Beck, 2007). The effects of local hydrodynamics and morphological conditions, as well as perturbations from storms, have played a large role in shoreline response. A recent trend in shoreline change has been accelerated erosion along the middle third of the island (Truitt, 1993). Lido Key coastal erosion has threatened commercial and residential structures, and continued erosion is expected to result in the loss of upland vegetation and sea turtle nesting habitat adjacent to the beach. Maintenance material dredged from New Pass has periodically been placed on Lido Key at Federal expense but has not been sufficient to maintain the beach and to prevent chronic erosion (USACE, 2002). Between 1964 and 1997 the USACE placed approximately 2.5 million cy of sand along the beaches of Lido Key (Beck and Wang, 2009). Because of the southward longshore transport in the region, sediment eventually eroded from Lido Key was carried to the Big Sarasota Pass ebb-tidal delta, which has been increasing in size as a result (Davis, Wang, and Beck, 2007).

Project Description

A beach erosion control project for Lido Key was authorized by the River and Harbor Act of December 31, 1970. It provided for beach restoration of 1.2 mi of the midsection of the Lido Key Gulf shoreline for protective and recreational purposes. The beach berm was about 125 ft wide, with an elevation 5 ft above mean low water and a natural slope seaward, as would be shaped by wave action. Periodic nourishment on an as-needed basis was part of the original authorization. Big Sarasota Pass, and to a lesser extent New Pass, were the sources of borrow material. An initial period of 10 years was established for Federal participation (USACE, 2002).

The City of Sarasota completed the northern half of the 1970 authorized project with sand dredged from New Pass without Federal participation. However, the project was never completed and was deauthorized on January 1, 1990 (USACE, 2002). Despite deauthorization, a Long-Range Beach Management and Erosion Control Plan was completed for the City of Sarasota in January 1991 (City of Sarasota, 2009). The plan recommended an initial beach renourishment of 350,000 cy with subsequent renourishments of 200,000 cy about every 4 years. The project area was approximately 1 mi of beach on central Lido Key. After an initial beach fill width of 155 ft, a design beach width of 75 ft was to be maintained for 50 years. Periodic beach restoration, as described in the Lido Beach Long-Range Beach Management and Erosion Control Plan, was to be in addition to and alternating with fill placed by the USACE from dredging of New Pass Channel, which was completed approximately every 4 years. The City Commission approved the plan and authorized the necessary studies to be performed. The City of Sarasota applied for a State grant for construction of the plan's initial fill through the Florida Beach Erosion Control Program for fiscal year 1997–98 (City of Sarasota, 2009). In April and May 1998, the City of Sarasota constructed the project along a 0.85 mi section of beach on Lido Key. Approximately 285,000 cy of sand were obtained from two offshore borrow areas located approximately 5 and 6 mi offshore in the Gulf, directly west of Lido Key (FSBPA, 2009).

The Water Resources Development Act of 1999 reauthorized the Lido Key Shore Protection Project, which allowed for continuation of the feasibility phase of the study. In response to severe erosion experienced in the region along the Gulf beach, 1.3 mi of the southern shoreline of Lido Key were nourished in March and April 2001 with 360,000 cy of sand obtained from a borrow area approximately 8 mi west of Lido Key Beach in 35 ft of water. In April 2002 the City Commission approved a plan to place "white" sand dredged from the maintenance of New Pass Channel by the USACE as a 2-ft-thick layer, approximately 100-ft wide, on the entire southern two-thirds of the island (City of Sarasota, 2009). The

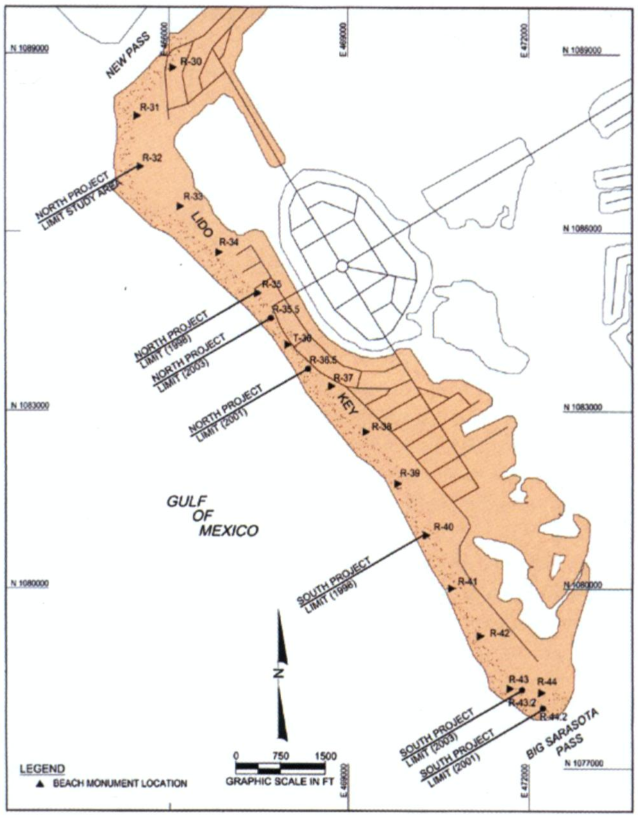

Figure 34. Lido Key beach nourishment performed in 1998, 2001, and 2003 (from FSU, 2008).

white sand was to cover the gray sand that was placed in previous nourishment efforts with more aesthetically pleasing material (Daughters, 2003). Between December 2002 and February 2003, approximately 125,000 cy of sand dredged by the USACE from New Pass Channel were placed along 1.5 mi of Lido Key shoreline. The nourishment efforts of 1998, 2001, and 2003 resulted in placement of approximately 770,000 cy of sand on Lido Key, advancing the high-water shoreline over 150 ft (Figure 34; FSBPA, 2009).

As of 2004, the Corps of Engineers no longer maintains New Pass Channel because of the federal funding cap being reached. Until new federal authorization is issued, federal dredging of the pass will be discontinued (Sarasota County, 2006). However, on December 22, 2004, the USACE Chief of Engineers signed the Feasibility Study for Hurricane and Storm Damage Reduction for Lido Key. Final steps to be completed before the Federal project is performed include the Project Cooperation Agreement between the USACE and the City of Sarasota and authorization by Congress for construction funding (City of Sarasota, 2009).

Hurricanes affecting the project area between 2004 and 2008 resulted in shoreline recession and loss of beach volume attributable to large storm waves, highlighting the need to restore Lido Key Beach to its previous condition. In March and April 2009 approximately 450,000 cy of sand excavated from New Pass channel and southern ebb shoal (Figure 35)

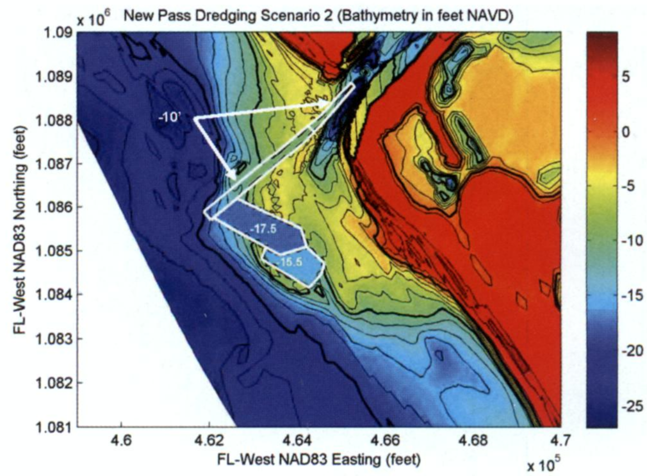

Figure 35. New Pass exterior navigation channel and southern ebb tidal shoal borrow areas used for the 2009 Lido Key Beach Renourishment Project (from Spadoni, Peirro, and Day, 2008).

were placed along a 1.54-mi segment of Lido Key as part of the Lido Key Beach Renourishment Project. This resulted in an average berm-width increase of 135 ft at an elevation of +3.9 ft North American Vertical Datum (NAVD). A challenge encountered during the 2009 Lido Key beach restoration project was identifying a high quality sand source. It was determined that the New Pass navigation channel contained desired sand but not in sufficient quantities. Extensive geotechnical investigations were conducted to determine if the ebb shoal off the north end of Lido Key could be an appropriate borrow area (FSBPA, 2009). Modeling indicated that the estimated effects of excavating the shoal fell within the natural historic variability of erosion patterns exhibited on Lido Key. It was estimated that refilling the borrow area cuts would take 24–60 years; therefore, the ebb shoal borrow area would be a single-use sand source. By using the outer edge of the ebb shoal, the landward portion remained intact and preserved sediment pathways across New Pass (Spadoni, Peirro,and Day, 2008).

The 2009 restoration of Lido Key Beach qualified for Federal Emergency Management Act (FEMA) funding to repair hurricane damage along the shoreline. Funding also was provided by the Florida Department of Environmental Protection and the City of Sarasota. The City also decided to place additional sand on the beach to address background erosion not related to the hurricanes to restore the beach back its 2003 width (FSBPA, 2009).

Currently a Comprehensive Inlet Management Plan is being conducted by Sarasota County. The study area includes Big Sarasota Pass, New Pass, and the adjacent interior and exterior shorelines of Longboat Key, Lido Key, and Siesta Key. The objectives are to determine the extent to which the inlets cause erosion on adjacent beaches and to provide for a reduction in impact, to develop a sand management strategy, and to provide for a safe and efficient navigation strategy. Key elements of the plan include bathymetric and topographic surveys; controlled aerial photography; erosion analyses; sediment data; hydrodynamic data; numerical modeling; and - identification, evaluation, and comparison of alternatives. In Phase I of the Management Plan, a regional workplan was developed by stakeholders. The County examined the physical and hydrodynamic setting of the passes and identified detailed activities required for final plan development (Phase II). Phase II of the Sarasota County Comprehensive Inlet Management Plan involved modeling and evaluation for feasibility, physical and environmental impact, and permit ability of the inlet management alternatives, which include "no action," dredging new alignments for channels at New Pass and Big Sarasota Pass, and mining Big Sarasota Pass ebb shoal (Coastal Tech, 2008).

The ebb-tidal delta at Big Sarasota Pass, located between Lido Key and Siesta Key, has increased in size as a result of erosion and southerly transport of material placed for nourishment of Lido Key. The ebb shoal is growing on the southern end and as littoral sediment is transported across the shoal; it is moving onto Siesta Key several hundred yards south of the northern end of the island, resulting in severe erosion to the north end of the key. In addition, littoral sand is shoaling the channel at Big Sarasota Pass, which has never been dredged, resulting in navigation difficulties. The ebb-tidal delta is composed of at least 10,000,000 cy of nourishment-quality quartz sand and is being further examined as a potential source of borrow material to be used in nourishment projects. Removal of the distal portion of the ebb shoal and dredging the distal portion of the inlet channel for nourishment purposes is predicted to have no negative impacts on the inlet or the northern portion of Siesta Key (Davis and Wang, 2004).

Project Outcomes

The beach and dune systems of Lido Key are crucial for protection of upland property and habitat that provide support to numerous plant and animal species (City of Sarasota, 2009). The restoration of Lido Key provided storm protection for upland roads and buildings. Land that had been lost to erosion was re-established and provides habitat for vegetation, nesting sea turtles, and shorebirds. Recreational beach area was restored for residents and tourists, which is an important part of the local and State of Florida economies. When coupled with dredging at New Pass Channel, the Lido Key nourishment projects provided the USACE with a location to deposit sediment dredged from the channel to maintain the pass for safe navigation.

RSM Principles Applied

Application of RSM principles for the Lido Key Beach Restoration project is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* Sand dredged from New Pass and offshore borrow sites have been used beneficially for Lido Key beach restoration. Big Sarasota Pass is being investigated to determine if the large resource of beach quality sand located in its ebb shoal can be dredged and placed beneficially to abate erosion on Lido Key. Because the direction of net littoral drift is to the south, sand sequestered in the Big Sarasota Pass ebb shoal is derived from Lido Key. As such, use of sand dredged from the ebb shoal for beach restoration on Lido Key fosters recycling of sand based on net sediment transport pathways (direction) and the sediment budget (quantities).

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* Because Sarasota County has developed and adopted a Comprehensive Inlet Management Plan, project-level decisions regarding dredging and placement of sand for habitat restoration can be made within the context of a regional sediment strategy instead of being project-specific.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* Federal, State, and local parties worked together to design and execute the multiple beach restoration/nourishment projects completed at Lido Key. New Pass dredging beneficial placement required interaction between the U.S. Corps of Engineers (performed the dredging) and the City of Sarasota (the local sponsor). For Phase I of the Comprehensive Inlet Management Plan, Sarasota County brought together stakeholders affected by the coupled inlet-shoreline system to develop a regional workplan.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* When evaluating sediment sources for the 2009 Lido Key Beach Restoration project, the regional transport system was closely examined and sediment was taken from the outer edge of the New Pass ebb shoal to avoid disrupting littoral transport of sand from Longboat Key to Lido Key. An Inlet Management Plan was formulated to include New Pass and Big Sarasota Pass, as well as the shorelines of Longboat Key, Lido Key, and Siesta Key. As such, regional sediment processes are being considered when evaluating borrow source alternatives, as opposed to site-specific project requirements at local scale.

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Not applicable for this project.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale.* The State of Florida systematically monitors beach changes at specific locations, including Lido Key. Beach profile surveys allow monitoring of cross-sectional changes, and aerial surveys are used to map shoreline position. Monitoring specific to beach restoration at Lido Key generally has not been completed, although past projects have all been small relative to those completed by the USACE.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* In support of Sarasota County's Comprehensive Inlet Management Plan, the USACE Jacksonville District was directed to perform a regional

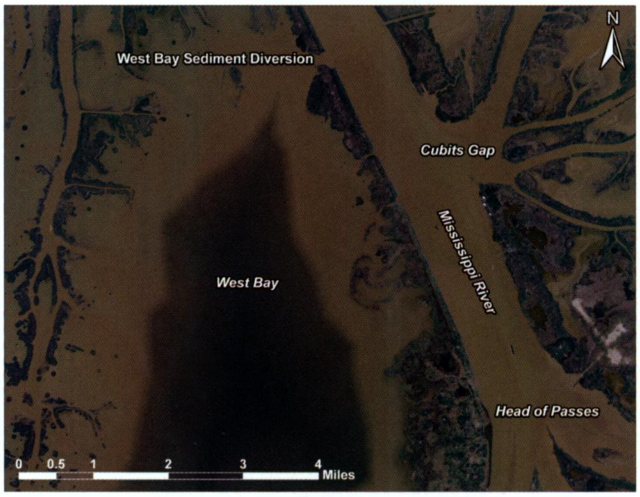

Figure 36. Location diagram for West Bay Sediment Diversion, Louisiana.

sediment study of the project area to develop an in-depth understanding of wave and tide forces that drive sediment transport processes and to construct an analytical model of the inlet system that includes regional sediment sources, sinks, and pathways that could be used for evaluating project alternatives (Bratos and Engle, 2008).

Lessons Learned and Recommendations

When performing beach restoration on Lido Key, the regional sediment system must be examined to assess project impacts associated with sediment extraction (channel/borrow site) and placement. This includes evaluating the interaction among sediment transport processes at Longboat Key, New Pass, Lido Key, Big Sarasota Pass, and Siesta Key. If structures are proposed (*e.g.,* groins along the southern end of Lido Key), a detailed assessment of potential negative impacts of structure placement must be completed to evaluate potential disruption of littoral sand transport to downdrift environments (Big Sarasota Pass and Siesta Key). If New Pass channel is dredged in the future, it is recommended that material be placed at erosional hotspots on Lido Key as it was in the past.

West Bay Sediment Diversion

Project Site Location

The West Bay Sediment Diversion Project (MR-03) is located on the west bank of the Mississippi River at river mile 4.7 above Head of Passes in Plaquemines Parish, SE Louisiana (Figure 36). The project area includes an artificial crevasse and the abandoned West Bay Sub-Delta Complex of the Mississippi River Delta: a large, shallow, open-ended interdistributary basin composed of 12% freshwater marsh and tidal flats and 88% open water, totaling 12,294 acres (Carter, 2003). Most of the West Bay seabed is subtidal and greater than 3 ft deep (Andrus, 2007).

The West Bay Sub-Delta Complex is one of six subdelta complexes comprising the most recent framework of the modern Mississippi River Birdfoot Delta. This subdelta originated around 1838 as a break in the natural levee of the Mississippi River just below the present day town of Venice during flood stage. A crevasse-splay was formed that allowed sediment to accrete and land building to begin in the newly opened area. By the mid 1900s the West Bay subdelta entered the natural deterioration stage, which was possibly accelerated by river channelization, canal dredging, and decreased sediment loads in the Mississippi River. Over time, as hydraulic efficiency of the system decreased, the input of fresh water, nutrients, and sediment from the Mississippi River diminished, and the sediment-deprived marsh deteriorated because of subsidence and erosion. Subsidence, estimated to be as high as 0.45 in/yr in the project region, and sediment deprivation are natural characteristics of abandoned deltas (Andrus and Bentley, 2007).

Project Description

Coastal Louisiana vegetated wetlands are vanishing at a rate of approximately 25 square mi per year because of degradation through submergence, mainly as a result of subsidence, sea-level rise, and lack of sediment input (USACE, 2001). In an effort to conserve and restore deltaic wetlands in Louisiana, the West Bay Sediment Diversion Project (MR-03) was implemented to create, nourish, and maintain 9831 acres of emergent fresh-to-intermediate marsh over the 20-year project life by enhancing the natural process of delta growth. This involved using a large-scale, uncontrolled sediment diversion through the west bank of the Mississippi River at mile 4.7 above Head of Passes and also beneficial placement of dredged material (Figure 37; Carter, 2003).

In November 1990, Congress enacted the CWPPRA. The CWPPRA directed formation of the Louisiana Coastal Wetlands Conservation and Restoration Task Force, which was given the task of developing a long-term restoration plan for Louisiana's coastal wetlands. West Bay Sediment Diversion was on their first priority project list submitted to Congress in November 1991 and was approved for funding sponsored by the LDNR and the USACE (Brown *et al.*, 2009; USACE, 2001). Project strategies established by the USACE included reintroducing alluvial sediment through the creation of a large, uncontrolled diversion channel and beneficially placing dredged material from channel construction, maintenance dredging, and relocation of a 10-in gas pipeline (Carter, 2003). Emergent marsh and associated coastal wetlands to be established by the diversion were considered a Category 2 resource by the U.S. Fish and Wildlife Service, a habitat of high value that is relatively scarce. The diversion was expected to provide beneficial secondary impacts of erosion control, increased fisheries productivity, and wildlife habitats. It was predicted that the sediment diversion would induce shoaling between river mile 1.5 and 5 above Head of Passes in the navigation channel of the Mississippi River because of a reduction in current velocity (how much was not

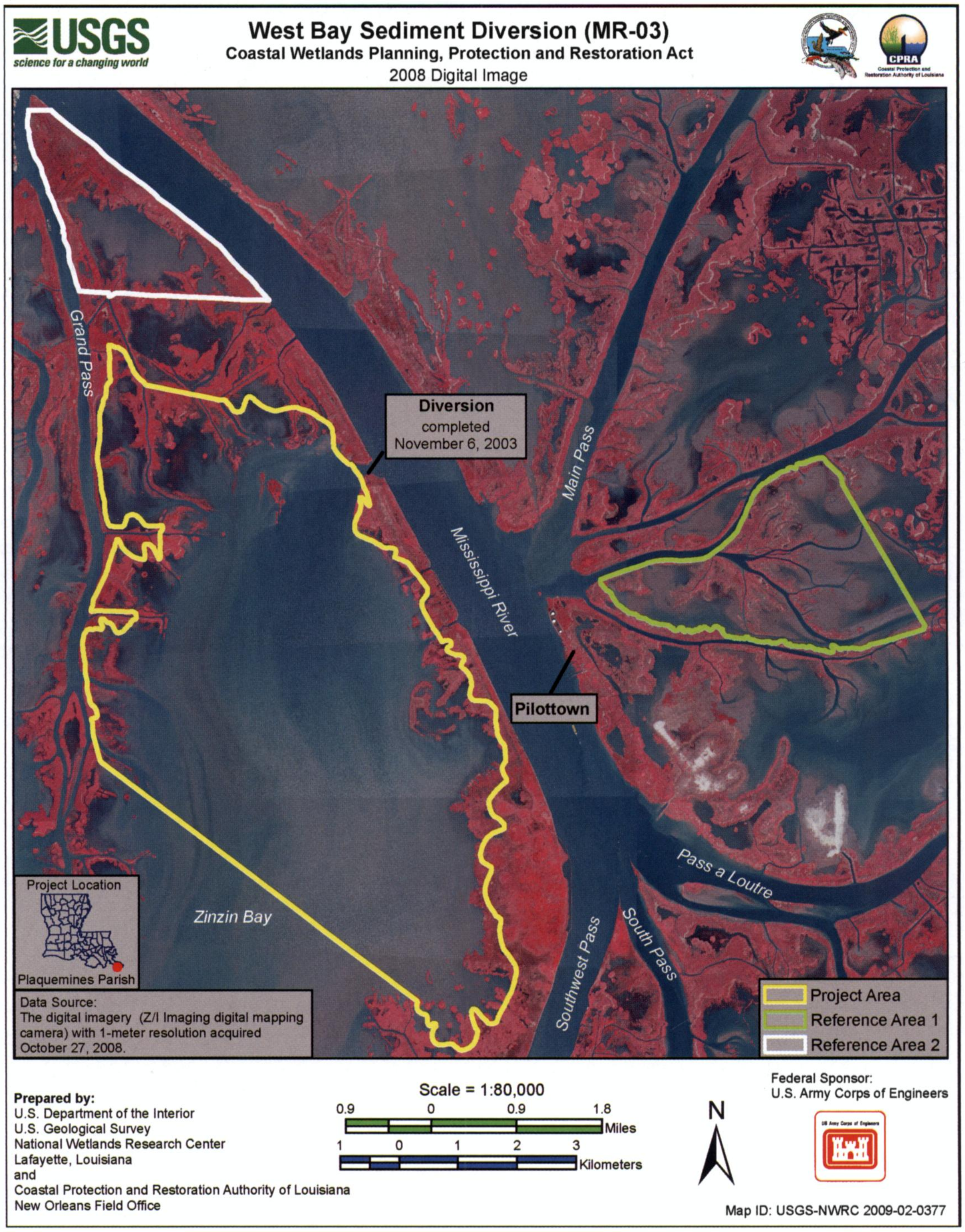

Figure 37. Extent of West Bay Sediment Diversion Project (MR-3) (from Carter, 2003).

known for such a large sediment diversion) and slightly increase saltwater intrusion in the river at the targeted diversion flow rate of 50,000 cubic ft per second (cfs) (USACE, 2001).

Although planning and engineering began in 1990, navigation concerns and land rights negotiations delayed construction until November 2003, when excavation of a diversion channel 25 ft deep and 195 ft wide was completed to deliver the initial design discharge of 20,000 cfs at the 50% duration stage of the Mississippi River at Venice, making it the largest constructed sediment diversion in Louisiana (Andrus and Bentley, 2007; Brown *et al.*, 2009). Material dredged during construction (655,000 cy from the diversion channel itself and 735,000 cy from the nearby shallow-draft anchorage area as advanced maintenance) was used to create wetlands within the shallow waters of West Bay (CWPPRA, 2010).

After sufficient monitoring of diversion characteristics, it was intended for the channel to be enlarged after 2 or 3 years so that a flow capacity of 50,000 cfs at the 50% duration stage of the Mississippi River at Venice would be reached (Brown *et al.*, 2009). A Monitoring Plan for the West Bay Sediment Diversion was prepared in 2003 for the State of LDNR Coastal Restoration Division (now the [OCPR]). Intensive monitoring of project effects was to be performed by the USACE Operations Division and included collection of discharge data, channel control surveys, and cross-sections. Additional monitoring by LDNR included land/water ratios, bathymetry/topography, and emergent vegetation (Carter, 2003). Emergency plans to close the diversion were developed in case hydrographic monitoring indicated the thalweg of the Mississippi River was migrating toward the diversion channel and in case shoaling in the nearby anchorage and navigation channel increased significantly, impacting navigation (USACE, 2001).

Project Outcomes

Measured discharge data from 2004 and 2005 showed a discharge for the diversion of 14,000 cfs at the 50% duration stage; the initial target discharge of 20,000 cfs was not reached. According to the measured discharge data in 2007 and 2008, capacity of the diversion had almost doubled to 27,000 cfs (Brown *et al.*, 2009). Recognized early on as a potential consequence of the diversion channel, increased shoaling did occur in the main navigation channel of the Mississippi River and the adjacent Pilottown Anchorage Area, a U.S. Coast Guard-designated safe harbor outside of the federally maintained navigation channel located along the west bank from river mile 1.5 to 6.7. The cost-sharing agreement between the State of Louisiana and the Corps of Engineers, as well as the budget approved by the Task Force in 2002, included project maintenance for the eastern 250-ft-wide strip of Pilottown Anchorage Area and the entire width of the adjoining access area between the anchorage area and the Mississippi River navigation channel (Brown *et al.*, 2009).

In 2006 maintenance dredging removed 1,240,000 cy of sediment from the shallow-draft anchorage previously dredged in 2003. In addition, initial dredging of the deep-draft anchorage between approximately river mile 6.4 and 4.7 removed 640,000 cy. Dredged material was placed in West Bay for wetlands creation through beneficial use of dredged material (Brown *et al.*, 2009).

On December 31, 2009, another Pilottown Anchorage Area maintenance dredging cycle was completed with the removal of approximately 1.8 million cy of sediment. Dredged material was used to construct two beneficial-use sites: a sediment-retention island perpendicular to the flow coming out of the West Bay conveyance channel and a site on the west bank of the Mississippi River downstream of the diversion (CWPPRA, 2010). The amount of maintenance dredging necessary and associated costs were much higher than originally anticipated, and studies were conducted to determine whether the West Bay Diversion was inducing shoaling in the Pilottown Anchorage Area and in the navigation channel of the Mississippi River.

Studies performed by the USACE ERDC indicated that the point bar (shoaled area) located within the Pilottown Anchorage Area was developing prior to construction of the diversion at a time corresponding to deepening of Grand Pass and Baptiste Collette, both located upstream of the project (Brown *et al.*, 2009). Studies suggested a loss of transporting power sufficient to induce shoaling of sandy sediment carried by the Mississippi River was caused by a loss of water (as much as 45%) through major upstream diversions (Grand Pass, Baptiste Collette, West Bay Diversion, and Cubits Gap), as well as from an increase in river width that begins upstream of West Bay Diversion. Modeling illustrated that the Mississippi River from river mile 7 to Head of Passes was aggradational with or without the West Bay Diversion. The diversion likely resulted in increased deposition rates in the anchorage area between the diversion channel and Cubits Gap. Furthermore, the amount of water and sediment being diverted and the characteristics of sediment being transported in the river are factors influencing the rate of shoaling. Modeling indicated that West Bay Sediment Diversion was responsible for 20–40% of the deposition in the combined dredging footprint of the anchorage area and the adjacent navigation channel. The percent for each individual footprint contains a higher level of uncertainty: 15–55% in the anchorage area and 10–30% in the adjacent navigation channel. Modeling also illustrated that the addition of the West Bay Sediment Diversion had shifted deposition closer to the center of the navigation channel, effectively contracting the cross-section of the channel (Brown *et al.*, 2009).

Initial stages of subdelta formation began in West Bay through diversion scour and increased flow capacity, formation of a distributary through the bay, and delivery of fine sediments to a depositional front (Andrus, 2007). According to Andrus (2007), following the typical subdelta growth curve, peak development of deltaic wetlands could be decades away. Since 2003, diversion of water and sediment into West Bay had not resulted in marsh creation. Factors preventing subaerial land development include wind and wave attack, bay-bottom depths, and a lack of estuarine enclosure. The latter, in the form of a Sediment Retention Enhancement Device (SRED), was initially proposed to enhance marsh building if necessary, but was never implemented. Satellite images suggested that major portions of fine-grain sediment bypassed the bay and were carried to the Gulf of Mexico. Monitoring indicated that receiving area configuration and trapping efficiency are important factors to consider when planning engineering strategies (Andrus, 2007). Since 2003, a total of 553 acres of fresh-to-intermediate marsh have been created in West Bay from beneficially using the dredged material of the Pilottown anchorage area (USACE, 2010).

On January 20, 2010, the CWPPRA Task Force voted to close the West Bay Diversion during the low-water period of 2010. Dredging costs for the Pilottown anchorage area had increased considerably more than originally projected. The closure decision was based on the fact that long-term costs to maintain and dredge anchorage areas near the project outweighed the benefits of the diversion. The Task Force approved continuing the project's 12-month work plan to gather valuable information, such as a better understanding of river sediment flow dynamics, which can be applied to future planning of other Mississippi River diversion projects. Furthermore, the CWPPRA Task Force is applying adaptive management to the West Bay Sediment Diversion Project to better inform decisions regarding the future of diversion projects in coastal Louisiana (USACE, 2010). West Bay closure construction is presently being planned and developed for Fall 2011. Closure options include (1) a semi-circle rock-dike closure in the receiving area, (2) a pumped-in earthen-ring closure in the receiving area, or (3) a pumped-in earthen-plug closure in the diversion channel itself (CWPPRA, 2010).

In order to efficiently use river sediment, there needs to be an advanced understanding of processes controlling sediment dispersal. Sediment analysis studies performed by Andrus (2007) indicated that sediment deposition in West Bay resulted from the diversion as well as from major storm events and river flows entering the study area from locations other than the diversion. The magnitudes and distribution patterns of sediment deposition in West Bay appeared to be related to the river hydrograph and corresponding diversion flows, as well as hurricane-related deposition and mixing. The exact balance between sediment retention in a bay and sediment bypassing to the shelf is unknown. Project design for maximum sediment retention is fundamental toward managing river sediments to build wetlands (Andrus and Bentley, 2007).

RSM Principles Applied

Application of RSM principles for the West Bay Sediment Diversion project is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* The goal of the project was to create marsh in a shallow bay by diverting and using sediment carried down the Mississippi River. In addition, dredged material from the Mississippi River channel and anchorage areas was placed in West Bay as beneficial use.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* Traditionally, sediment dredged from the Mississippi River channel has been transported down the channel and offshore to the detriment of marsh and bay habitat. The intent of West Bay and other sediment diversions is to allow sediment and water from the river to enter marsh and bay environments periodically, as it would have under natural conditions prior to the construction of levees and stone protection structures along the banks of the river channels.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* CWPPRA projects require systematic coordination among Federal, State, and local resource managers on coastal restoration projects. Prior to project implementation, studies are conducted to identify and quantify intended benefits of the proposed project and potential adverse impacts. For the West Bay Diversion project, modeling results indicated that channel shoaling may result from the project, so this impact was monitored carefully. A shift in channel shoaling was encountered and dredging was required. Unfortunately, increased dredging costs exceeded the project budget, requiring closure of the diversion.

(4) *Make local project decisions in the context of the sediment system and consider the regional implications.* Project closure is scheduled to occur in Fall 2011 after much consideration of local benefits to the marshes and bay environments relative to regional navigation considerations. The West Bay project was not able to produce the amount of subaerial marsh stated in the project objectives, and increased shoaling in certain portions of the Mississippi River navigation channel resulted in unexpected costs relative to expected project benefits. As such, the decision was made to close the diversion in Fall 2011 in consideration of regional implications of shoaling on navigation safety and unrealized local project benefits.

(5) *Integrate a systems approach to the management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* River sediment was intended as a source for re-establishing marshes in West Bay. River sediment was a practical source for West Bay given the size of the bay and the ability of the river to deliver sediment once the conveyance channel was opened through the bank of the Mississippi River.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at local and regional scale.* Even though the West Bay Sediment Diversion Project is being closed without the creation of marsh as planned, the project is serving as a lesson for future diversion projects. Adaptive Management is being applied to recognize where this project went wrong and to gain a better understanding of sediment transport and channel shoaling processes in the Mississippi River.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* Prior to initiating the West Bay Sediment Diversion Project, significant technical evaluation of riverine sediment transport processes and marsh and bay sedimentation was conducted to evaluate the benefit of increased sediment to West Bay and the potential adverse impacts of levee breaching on channel navigation. Increased navigation channel shoaling was predicted, but the magnitude of shoaling relative to the marsh creation in West Bay was not well predicted.

Lessons Learned and Recommendations

CWPPRA was designed with the principles of RSM in mind to effectively restore and protect wetland habitat in coastal Louisiana. This has required close coordination among Federal, State, and local resource managers since the program was initiated in the 1990s and extensive technical evaluation of the processes influencing wetland change on the Mississippi River Deltaic Plain. Although significant applied research has been completed in this area over the past 30 years, a comprehensive sediment management plan for coastal Louisiana has only been in development for the past 5 years or so. Lessons learned from existing CWPPRA projects provide a foundation upon which the Louisiana sediment management plan has evolved. The following are observations for the West Bay Sediment Diversion Project.

(1) The West Bay Sediment Diversion was the first major uncontrolled sediment diversion project in coastal Louisiana. From the beginning it was recognized as a demonstration/ pilot project, and lessons learned from the project are expected to benefit future sediment management considerations and sediment diversion projects.
(2) Project budgets should not include maintenance of adjacent affected areas without knowing how much the expense will be in the future. The budget of the West Bay Sediment Diversion Project included maintenance of the Pilottown Anchorage Area. Although it was anticipated to shoal, the amount of shoaling, and therefore the associated costs, were unknown. Ultimately, costs to dredge the anchorage area exceeded the project budget and led to closure of the project.
(3) Greater consideration should have been given toward retaining sediment diverted into West Bay. A retaining structure was proposed for enhancing sedimentation in the northern portion of West Bay, but the structure was never constructed. Shoaling in the main channel of the Mississippi River became an issue and the main focus of the project because of the expense associated with maintenance dredging. A retainment structure in West Bay may have enhanced sediment accretion in the bay and reduced the velocity of the water in the conveyance channel, thereby increasing the velocity in the main channel and reducing shoaling.
(4) West Bay was not a good choice for a diversion project in terms of depth and proximity to the Gulf of Mexico. Marsh building, particularly in a relatively deep bay, takes time. A shallower receiving basin for marsh creation may have accreted faster, resulting in less sediment loss to the Gulf of Mexico. A better contained diversion outflow area may have yielded better results as well.
(5) Although marsh creation is the ultimate goal for most restoration projects, shallow subtidal seabeds created in West Bay via diversion also provides valuable habitat.
(6) Even though the West Bay diversion is scheduled to close in Fall 2011, dredged material from the Mississippi River navigation channel and Pilottown Anchorage Area should continue to be placed on the interior bank of West Bay for marsh creation through the small cuts in the bank opposite Cubits Gap.

West Galveston Island Beneficial-Use Project

Project Site Location

Galveston Island is a developed barrier island complex that separates West Bay from the Gulf of Mexico along the Upper Texas Gulf Coast. The island extends approximately 29 mi in a NE-SW direction from Galveston Bay Entrance (Bolivar Roads) to San Luis Pass (Figure 38; Giardino, Bednarz, and Bryan, 2000).

Figure 38. Location diagram of Galveston Island, Texas.

Prominent beach ridges on the island mark an initial history of island growth that began approximately 5500 years ago and lasted at least 1800 years, followed by landward retreat (Wallace, Anderson, and Rodriguez, 2009). On the Gulf side, diurnal tides have a typical range of 0.5 to 1.5 ft (PIE, 2002). Wave heights are usually less than 3 ft but can reach over 20 ft during extreme storm events. As a result of prevailing winds from the SE, longshore currents flow predominantly to the west (Wallace, Anderson, and Rodriguez, 2009). Net longshore sediment transport is estimated to be approximately 150,000 cy/yr to the SW (Ravens and Sitanggang, 2007). Littoral sediment transport has caused Galveston Island to accrete to the west, creating a younger section of the island that is narrower and thinner. While the eastern third of the island is protected by a seawall, storm washover features dominate the barrier landscape of West Galveston Island (Wallace, Anderson, and Rodriguez, 2009).

In response to the 1900 hurricane on Galveston Island, a seawall was built on the eastern third of the island to provide protection from future extreme events. Federal and Galveston County funds were used for construction of the flood control structure and the increased surface elevation behind the wall with sand fill. The seawall has an elevation of about 18 ft and extends approximately 10 mi along Galveston Island, of which more than 7 mi are along the Gulf shoreline (Morton, 1988). The remaining 3 mi of seawall are inland now because of the growth of East Beach from periodic longshore transport from the SE and deposition along the south side of the south jetty (Morang, 2006). After the seawall was constructed, the beach in front of the structure began to erode. A series of groins and revetments was constructed in an effort to maintain the beach and protect the toe of the seawall (Figure 39; Ravens and Sitanggang, 2007).

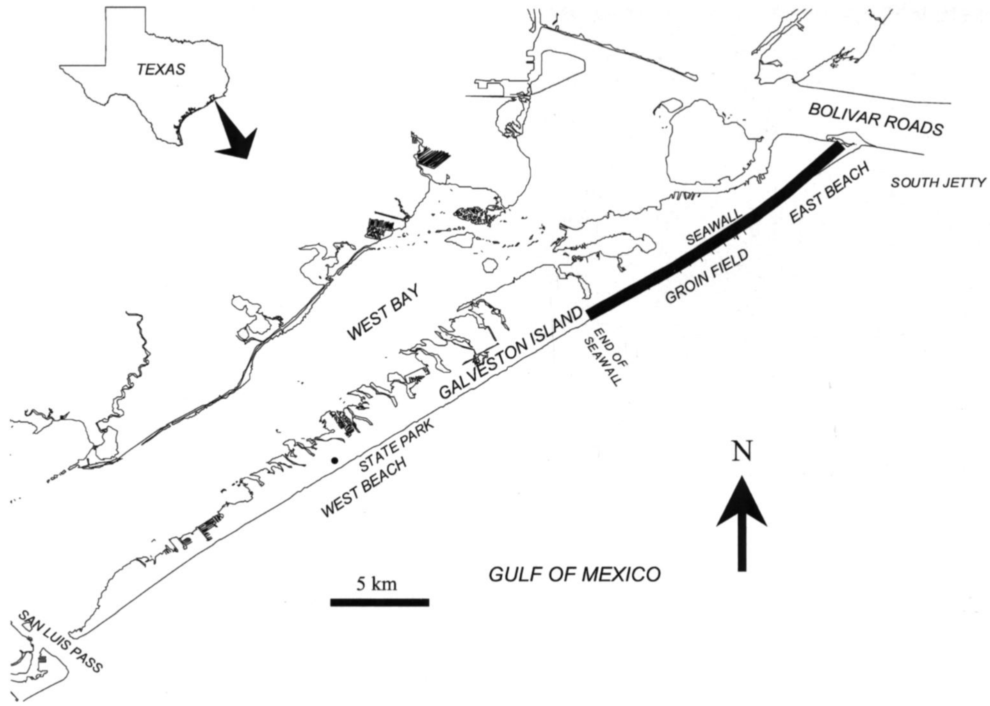

Figure 39. Structures on and adjacent to Galveston Island, including jetties securing the entrance to Galveston Bay, seawall, and groins (from Ravens and Sitanggang, 2006).

Shoreline recession along Galveston Island has been the result of natural and anthropogenic factors. These include sediment-movement offshore under-wave processes during extreme storms, subsidence, sea-level rise, sediment loss to the San Luis Pass tidal delta, sediment loss to West Bay from overwash events and through aeolian transport, reduced sediment supply from dredging, and reduced sediment supply from coastal engineering structures (*e.g.,* jetties, seawall, groins) (PIE, 2002). The western (downdrift) end of the island has experienced the highest rates of erosion with recession rates of 5 to 15 ft per year (FEMA, 2009). Land loss and erosion on the bay side of Galveston Island has primarily been the result of marsh drowning attributable to subsidence, sea-level rise, and exposure to waves (Darnell, 2005).

Projects

Land loss on Galveston Island threatens habitat, public and private buildings and structures, mainland protection, and tourism on the island. Because of high rates of erosion/land loss, various private and public restoration/nourishment projects have been performed on the island. Specific information for all projects was not readily accessible. Many projects were funded through the Coastal Erosion Planning and Response Act (CEPRA), which was implemented by the TGLO in 1999. The program involves a coordinated effort between State, Federal, and local entities to carry out coastal erosion response projects and studies (TGLO, 2007). The CEPRA projects include beach nourishment, dune restoration, marsh restoration, shoreline protection, bird habitat restoration, and beneficial use of dredged material (Newby, 2006); CEPRA studies include shoreline studies and monitoring of specific projects to obtain data sets necessary for project designs. In addition, the CEPRA program has been involved in funding sand-source evaluations for potential beach fill projects (McKenna, 2009).

Galveston Island Bayside. Multiple restoration projects have taken place on the bayside of West Galveston Island including, from west to east: Isla Del Sol, Jumbile Cove, Galveston Island State Park (GISP), Delehide Cove, and Starvation Cove (Figure 40). These projects used sandy sediment dredged from the bottom of West Bay and from dredging nearby small-craft navigation channels to create marsh habitat in the form of mounds and terraces. Geotextile tube breakwaters were used to protect project areas from wave erosion.

The GISP Wetlands Restoration Project began in 1997 when the Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service secured a grant from the National Coastal Wetlands Grant Program using Galveston Bay Estuary Program and Natural Resource Damage Assessment funds from the Apex barge spill settlement for the local match. A Task Force consisting of members from Federal, State, and local agencies was organized to manage the project (Glass and Hollingsworth, 1999). In 1999 terraces were constructed from sediment excavated from the bay bottom in the project region (Carancahua Cove) in the pattern of a checkerboard. Terrace ridges were subsequently planted with *Spartina alterniflora*. This technique was used to convert

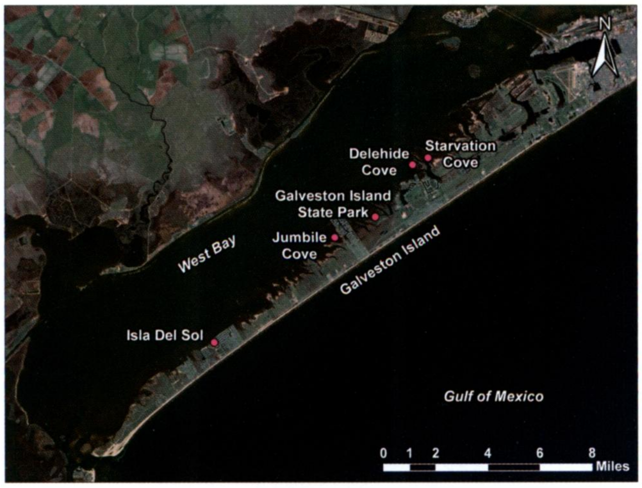

Figure 40. Restoration project locations on the West Bay side of Galveston Island.

shallow subtidal bottom to intertidal wetlands (Rozas and Minello, 2007). Sand-filled geotextile tubes were constructed to protect the area from wave erosion (Darnell, 2005). Monitoring established for the project included aerial photography to track the spread of vegetation and natural evolution of the new marsh and bird and wildlife monitoring to evaluate habitat. Lessons learned from the GISP Restoration Project were applied to other marsh restoration projects in the area (Glass and Hollingsworth, 1999).

The Jumbile Cove Wetland Protection and Restoration Project was sponsored by the Texas Parks and Wildlife Department. The goal was to slow or halt erosion in Jumbile Cove marshes and restore intertidal marsh and bird nesting habitat. Initial project design consisted of terracing with no breakwater, but erosion patterns associated with the GISP terraces prompted a design change to construction of dredged material mounds and a geotextile breakwater. In 2001, Phase I involved construction of 2800 ft of geotextile tubes, 35 marsh mounds, and two bird nesting mounds with fringe marsh. In 2004, Phase II involved construction of 66 more marsh mounds (O'Brien, 2006). The mounds were created by hydraulically dredging material from a nearby borrow site in West Bay (GBIC, 2011).

In the fall of 2003, Delehide Cove Wetlands Restoration and Protection Project was constructed on the backside of Galveston Island. The project team consisted of the TGLO, Texas Parks and Wildlife Department, U.S. Fish and Wildlife Service, National Marine Fisheries Service, Galveston Bay Foundation, and West Galveston Island Property Owner's Association and was funded through the CEPRA. Project goals were to restore 50 acres of estuarine intertidal marsh and 1 acre of seagrass. Strategies included constructing shoreline protection structures to shelter against destructive wave action and placement of dredged material to restore lost wetlands. When the project was finished, 8200 linear ft of geotextile tube breakwater were constructed, 14,500 cy of dredged sediment was placed, and 75 habitat mounds were created. The Delehide Cove project included beneficial use of maintenance material dredged from boat channels at the adjacent Pirates' Cove Subdivision. This borrow material was considered to be a practical source for marsh creation to supplement the habitat mounds (Shiner Moseley and Associates, 2003a).

In 2005, Starvation Cove Restoration Project was completed by the Texas Parks and Wildlife Department in conjunction with the TGLO (GBF, 2011). Project design was based on a detailed assessment and understanding of existing and historical site conditions at the project area and lessons learned from previous projects. The restoration strategy for the project involved construction of mounds formed by hydraulic placement of sandy dredged material and plantings. In addition, geotextile breakwaters were placed along the marsh fringe that forms the western boundary of Starvation Cove (Darnell, 2005). In 2007, Delehide-Starvation Cove Gap Project was completed, which involved placement of 800 linear ft of geotextile tube breakwater to connect the two previously constructed projects (GBF, 2011).

The Isla Del Sol Shoreline Protection and Habitat Restoration Project was completed in 2007. Approximately 29,000 cy of sandy maintenance material dredged from the local small-craft entrance channel was used to fill 1100 ft of geotube breakwater to serve as a protective shoreline wave break and create approximately 12 acres of intertidal marsh and sandflat islands. With help from volunteers the marsh islands were planted with smooth cordgrass. This project served as an example for other bayside communities with an interest in doing their part to protect and restore habitat in West Bay (Young, 2007).

In the fall of 2010 the West Galveston Island Estuarine Restoration Project was constructed in Jumbile and Carancahua Coves (Figure 41). Funding was provided by the TGLO (CEPRA Program) and National Oceanic and Atmospheric Administration (American Recovery and Reinvestment Act). Approximately 810,000 cy of sandy sediment were dredged from the adjacent open bay to create an estuarine marsh complex. One hundred thirty acres of mound-design marsh were created in Jumbile Cove, and about 198 acres of terrace/mound design marshes were created in the Carancahua Cove portion of GISP. The project restored previous restoration efforts, including replacing the terrace marshes constructed in GISP, which had eroded to a subtidal elevation, and enhancing the existing marsh mounds at Jumbile Cove. Improved habitat in the project area serves to improve habitat functions related to storm/flood protection, fishing, recreation, and water quality (Krecic *et al.*, 2011).

Galveston Island Gulf Side: Seawall. Numerous restoration projects have been constructed on the Gulf of Mexico side of Galveston Island, primarily to restore beaches fronting and west of the seawall. In addition to larger scale projects, sand fill has been imported from deposition at East Beach or other sources at various times and locations and placed at isolated locations along the seawall beach and West Beach (PIE, 2002). While the seawall protects the eastern third of Galveston Island from storm impacts, the beach in front of the seawall experiences erosion. The City of Galveston has

Figure 41. West Galveston Island Estuarine Restoration Project (from Krecic *et al.*, 2011).

been concerned with retaining a beach in front of the seawall to attract tourists and protect the structure. Groins were built to trap sand, and the city and private interests have nourished the beach at various times (Morang, 2006).

In 1985 a small-scale beach nourishment project involved the placement of approximately 15,000 cy of material on a 1500-ft section of San Luis Beach in front of the San Luis Hotel. Beach nourishment material, which had a smaller grain size than native beach material, was dredged from a back bay location near the eastern end of Galveston Island. Postproject monitoring concluded that beach material was found to have left the system through suspension and subsequent movement offshore, end loss, profile adjustment, and aeolian transport (Giardino, Bednarz, and Bryan, 2000).

In 1993 the Galveston Berm Construction Project was completed using approximately 500,000 cy of maintenance material (greater than 60% sand) dredged by the USACE from the Galveston Channel to construct a nearshore berm about 1 mi offshore Galveston. Postproject monitoring indicated a loss of material attributable to winnowing of fine-grained sediment, movement of sand into the littoral zone, and wave impact on the berm (Gilbreath and McLellan, 1994).

In 1995 a beach nourishment project was constructed in a 3.6-mi project area in front of the seawall within the groin field fronting the City of Galveston beach. The purpose of the project was to provide a recreational beach for island residents and tourists on Galveston Island. The initial planned borrow source was Big Reef shoal located in Bolivar Roads just north of the south jetty. Because of project scale and the marginal amount of sand located in the shoal, cost to dredge and transport sediment to the restoration site, potential dredging losses of fine-grained sediment, and a hardpan layer within the potential sand source, a detailed sand search was performed to find a more beneficial source of material. Ultimately, a more practical and economic sand source was chosen seaward of the project site that contained a deep sand layer (Spadoni, 1996). Approximately 590,000 cy of material were placed on the beach, restoring recreational area for residents and tourists (Morang, 2006).

Galveston Island Gulf Side: West of Seawall. Beaches west of the Galveston Island seawall have been nourished at various times by an assortment of project sponsors. In 2001, the West Beach sand fill project was completed. Approximately 13,000 linear ft of shoreline were nourished through the placement of about 65,000 cy of sand as small-scale beach fills. The project was funded through CEPRA Cycle I in cooperation with the City of Galveston and several West Galveston Island homeowner associations (McKenna, 2009). A project site follow-up in 2002 indicated that very little of the beach fill remained (PIE, 2002).

In 2003, again funded through CEPRA, the TGLO and City of Galveston completed a beach restoration project at the west end of the seawall. The goal was to identify a sustainable borrow source as part of a long-term beach management strategy for the project site. Big Reef, which was identified as an accretional feature by the USACE, was the selected sand borrow source. Approximately 80,000 cy of sand were dredged from the shoal, placed in a temporary dredged material PA, and then hauled 10 mi by truck to the project site. A secondary outcome of the project was improved water exchange for the lagoon adjacent to Big Reef (Shiner Moseley and Associates, 2003b).

Storm surge and wave action resulting from Hurricane Ike in 2008 caused an average of 136 ft of shoreline recession on 5.8 mi of beach between the western end of the seawall and eastern end of GISP, leading to a large-scale beach restoration plan. The Beach Dune System Restoration at West Galveston Island Project was designed to restore the beach profile to prestorm conditions (FEMA, 2009). Project sponsors included the TGLO, City of Galveston, and Galveston County. The project plan consisted of placing 1.8 million cy of beach quality sand on the Gulf side of Galveston Island. This would extend the shoreline 400 ft seaward from the high-water line, helping to buffer the island against future storm damages, restore wildlife habitat, and protect local and state recreation and economic benefits (FEMA, 2009). Sand would be dredged from submerged sand sources in the region of Bolivar Roads, including the anchorage basin borrow source and south jetty borrow source and then graded to form a restored beach and dune system. The project was designed to act as a feeder beach for down-drift beaches on Galveston Island. However, the West Galveston Island Beach Restoration was canceled by the TGLO on November 15, 2010 (TGLO, 2010). The project would have been funded by the TGLO (CEPRA Program) with a combination of local, State, and Federal funds; however, legal issues regarding the definition of the public beach easement delayed the project indefinitely and ultimately led to its cancelation because of delay costs being in the millions.

Project Outcomes

Multiple habitat restoration, creation, and protection projects along West Galveston Island have enhanced habitat and added sediment to the Galveston Island littoral system. Restoration projects on the bay side of Galveston Island have restored marsh in West Bay and provided protection from wave erosion, resulting in new and improved habitat. Beach restoration projects on the Gulf side of the island temporarily increased beach width but permanently added sand to the littoral zone (enhancing the island sediment budget). Although there may have been missed opportunities for beneficial use of sediment dredged from small-craft navigation channels by private interests, most of the larger projects on the bay side of Galveston Island have resulted in restored/created habitat and/or the construction of geotubes for shoreline and habitat protection. Overall, project benefits include restored wetland habitat for wildlife, better shoreline protection from erosion and storms, and restored beach habitat for recreation.

RSM Principles Applied

Application of RSM principles for the West Galveston Island projects is as follows.

(1) *Recognize sediment as a valuable resource that is integral to the economic and environmental vitality of the area.* The TGLO, in coordination with other State, Federal, and local organizations, oversees many wetland restoration and shoreline protection projects along the coast. A significant component of oversight is to assure that projects are being constructed within the context of RSM practices and procedures, in other words, recognize sediment as a valuable resource. Sediment placement and retention within the transport system is crucial for limiting land loss experienced on Galveston Island. Material derived from a variety of borrow sources on and near the island has been used for marsh creation and beach restoration.

(2) *Seek opportunities to implement RSM practices and procedures to improve sediment management.* Material dredged from local small-craft navigation channels and open bay bottom on the bay side of the island has been used for marsh creation and shoreline protection. Implementation of CEPRA is aimed at ensuring RSM practices and procedures are applied for large Federal and State projects as well as small private projects that are common along the West Bay shoreline.

(3) *Coordinate with project partners and stakeholders when evaluating, formulating, and implementing RSM plans, practices, and procedures.* For all medium-to-large habitat restoration/creation, shoreline protection, and channel dredging projects, substantial coordination is required during all levels of project planning and construction. This may not always be the case for small-scale private projects where dredging/placement quantities are relatively minor. However, a large number of small projects can quickly become a medium-sized project that could significantly impact habitat health and shoreline stability. There have been private, small-scale, site-specific projects completed on the island (particularly along West Bay) that may have been more beneficial if collaboration among interested parties was well-coordinated. That being said, information available on the beneficial use of dredged material from small-craft channels along the back side of West Bay indicates that this material is being used to enhance wetland habitat along the bay shoreline on a case-by-case basis. This may be the result of CEPRA providing or requiring expert oversight for projects.

(4) *Make local project decisions in the context of the sediment system and consider regional implications.* All projects on the Gulf side of West Galveston Island consider regional sediment transport processes and implications of proposed actions when beach restoration and protection are primary goals. This process is not as clear for the bay side projects where sediment transport processes are less regular and much smaller in magnitude.

(5) *Integrate a systems approach to management of sediment from upland sources, through river systems, into estuaries, and along coastal regions.* Not applicable for this project.

(6) *Monitor projects to evaluate the physical, environmental, and social impacts at the local and regional scale.* Data collected and practical experience obtained from habitat restoration/creation and shoreline protection projects along West Galveston Island have served as important information for the design of subsequent projects. Project strategies employed on the island, including marsh mounds, terraces, geotextile breakwaters, and sand fill techniques, have been evaluated and refined to improve future project performance.

(7) *Apply technical knowledge, tools, and use available resources to understand the dynamics of local and regional systems prior to and following actions to improve management of sediment.* A comprehensive understanding of sediment transport processes and geomorphic response affecting a project area is required for efficient project implementation. Coordination among Federal, State, and local stakeholders provides a measured level of technical knowledge, tools, and available resources as guidance for effective project planning and performance. The CEPRA funded studies are used to identify appropriate borrow sources around Galveston Island for beach restoration. Morang (2006) developed a conceptual sediment budget for the area between Sabine Pass to San Luis Pass. Sources of data for the budget included dredging data beginning in the 1970s, beach fill quantities, sediment grain-size statistics, aerial photography, shoreline data, and various literature and historical sources. This information is invaluable for understanding regional sediment transport processes and the impact of proposed projects on those processes.

Lessons Learned and Recommendations

Coordination among all parties potentially impacted by proposed dredging or placement is a benefit, regardless of project size. The intent of regulations related to proposed projects should be to foster communication and require expertise to ensure project success with minimal impact to coastal wetlands. It appears that most actions along the bay shoreline related to small-craft channel dredging have embraced the concept of beneficial use of sediment by placing dredged material in close proximity to the dredged site to enhance or protect wetlands (*i.e.,* keep sediment within the local system). Along the Gulf side of Galveston Island, the seawall protects a northern portion of the island and jetties protect the entrance to Galveston Bay; however, both exacerbate erosion along the SW portion of the island by blocking natural longshore sand transport. Beach restoration is necessary to supply sediment that would naturally be delivered in the absence of updrift structures. Projects should always be designed to incorporate optimum utilization of sediment resources in a project area to improve habitat and provide protection to the island and regional transport system.

CONCLUSIONS AND RECOMMENDATIONS

The 11 case studies evaluated as part of the GRSMMP provided a wide variety of habitat types, restoration goals, and project sizes. As such, each study developed its own specific approach to habitat restoration/creation, habitat conservation, and beneficial use of sediment required for restoration. Although the initial intent was to group projects as "success stories" or "missed opportunities," it became evident that all projects likely had some missed opportunities (some more than others), and all projects contained successful components. In every case the underlying theme associated with restoration or conservation was effective use of sediment. Whether from channel dredging, borrow sites, or bay bottom, stakeholders were always interested in using sediment most effectively for their project. Upland disposal of dredged material for bird habitat to avoid adverse impacts of increased turbidity on seagrass beds worked well for Laguna Madre, but Louisiana used that type of material for containment dikes and marsh restoration. In both cases, sediment was used to benefit habitat restoration rather than being disposed of outside the active sediment system. In other words, sediment use was driven by project goals.

The primary recommendation centers around background knowledge required to make effective decisions regarding site selection, restoration design, and proper monitoring. One can never have enough information for making the "best" decision. However, in most cases, adequate information exists to make informed decisions. There is generally a significant amount of information to draw upon (reanalyze) when evaluating potential impacts of proposed actions; however, information regarding potential regional or cumulative impacts may be overlooked because it is too time consuming to evaluate. Make the time and effort to creatively address all sediment management issues that may influence project success. Doubt cast by poor project design has long lasting impacts that are difficult to overcome.

Finally, clear and consistent communication among all stakeholders is paramount to project success. In all case studies, communication among Federal, State, and local interests appeared to be quite productive. Modern environmental regulations require this action as part of the consistency process, but addressing issues early in the process builds confidence among stakeholders and a level of trust that often carries through the project approval process.

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